Journal

WATER POLLUTION CONTROL FEDERATION

FORMERLY SEWAGE AND INDUSTRIAL WASTES

ANNUAL CONVENTION ISSUE

Stabilization Ponds—Van Heuvelen et al.

Phosphate Processing Wastes—Specht

Bio-Oxidation Studies—Busch and Myrick

Wet Oxidation of Sludge—Hurwitz and Dundas

Toxicity of Waste to Marine Organisms—Hood et al.

Operator's Corner

Operator's Manual, Sedimentation

Program—Page 1028

Thirty-Third Annual Meeting—Oct. 2–6, 1960
Convention Hall and Sheraton Hotel, Philadelphia, Pa.

SEPTEMBER 1960

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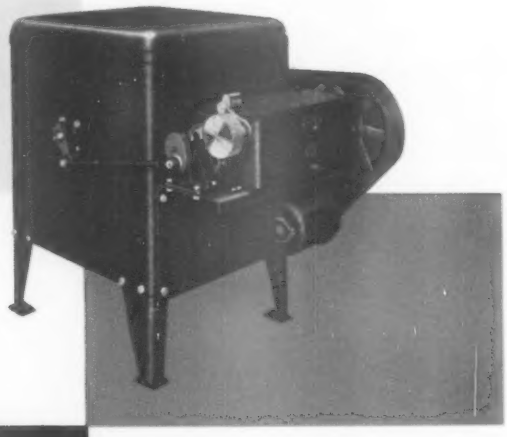

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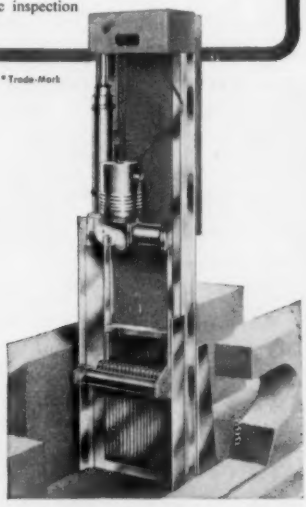

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Volume 32 | September 1960 | Number 9

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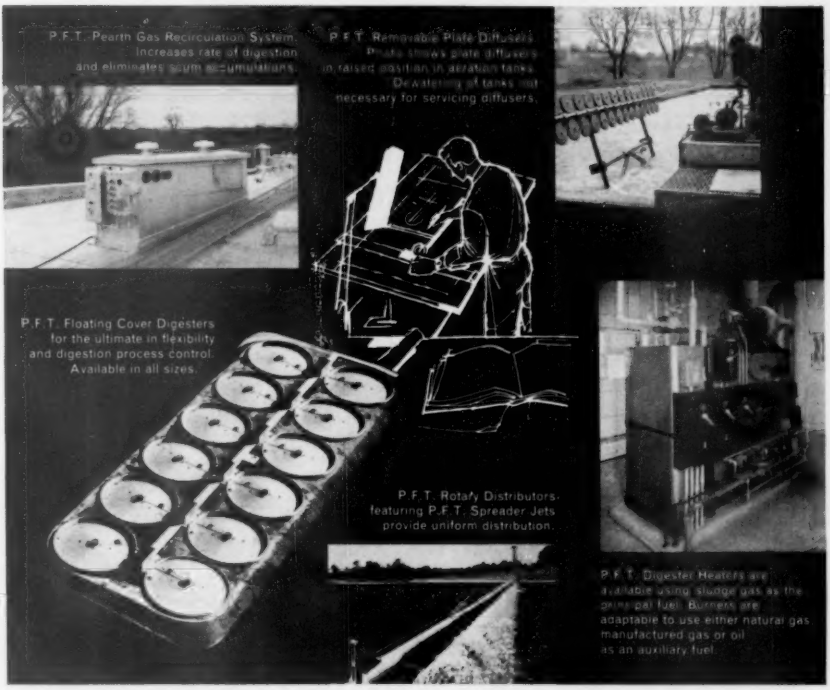
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EDITORIAL AND EXECUTIVE OFFICES: 4435 Wisconsin Ave., N.W., Washington 16, D. C. Send all manuscripts, advertising copy, subscriptions, address changes, etc., to this address. JOURNAL WPCF is published monthly by the Water Pollution Control Federation at Prince & Lemon Sts., Lancaster, Pa.

SUBSCRIPTION RATES: Members of local associations affiliated with the Federation, $8.00 per year. Nonmembers, U. S. and Canada: $10.00; other countries, $11.50. (Foreign subscriptions must be accompanied by International Money Order.) Single copies: United States, $1.25 each; Foreign, $1.50 each.

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Library of Congress Catalog Card Number: 42-19992.

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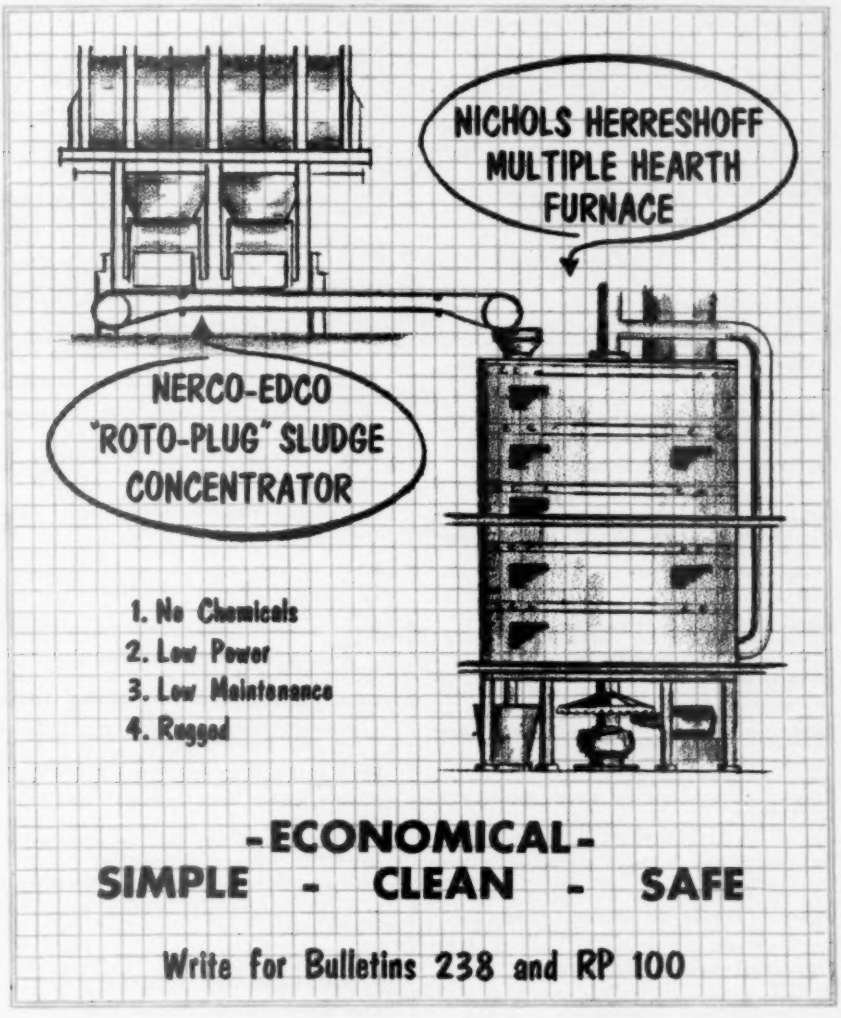

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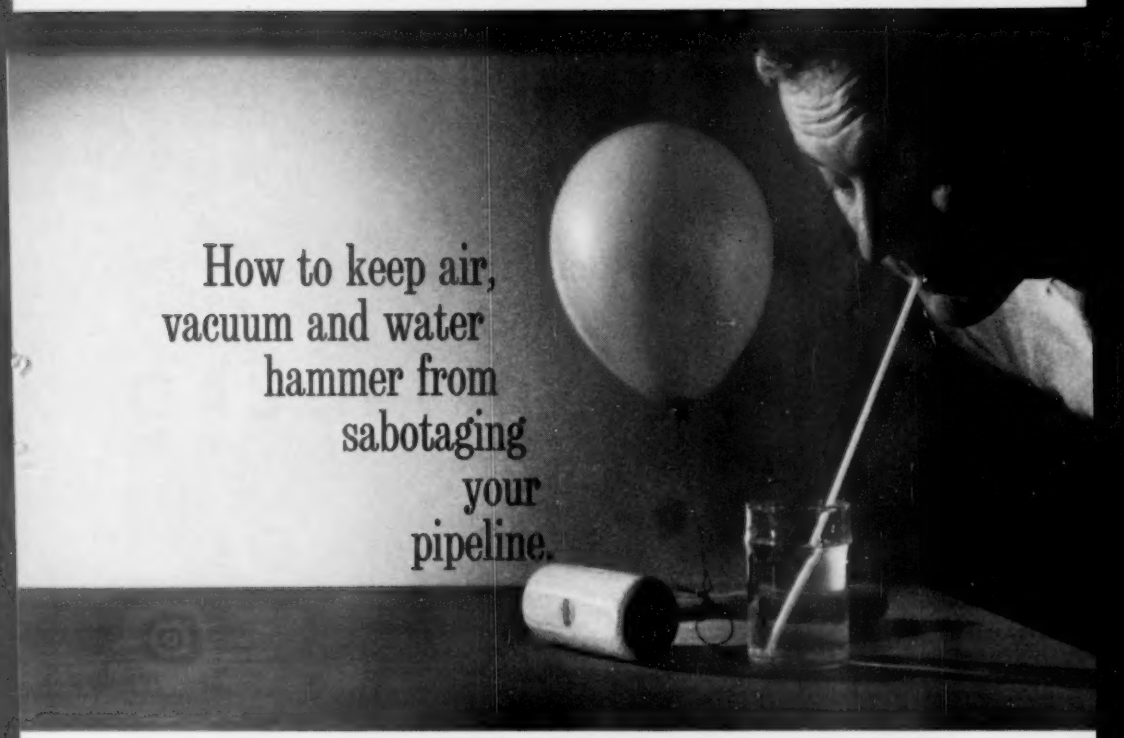

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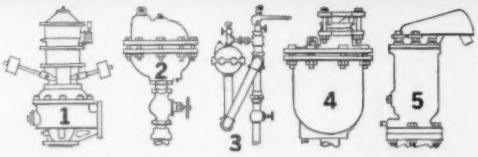

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Switzerland	Sept. 23–24	Tessin, Switzerland
Missouri	Sept. 25–27	Hotel Governor, Jefferson City
North Dakota	Oct. 5–7	Grand Pacific Hotel, Bismarck
Pacific Northwest	Oct. 20–22	Marcus Whitman Hotel, Walla Walla, Wash.
Canada	Oct. 23–26	Sheraton-Brock, Niagara Falls, Ontario (new date and place)
Rocky Mountain	Oct. 24–26	Broadmoor Hotel, Colorado Springs, Colo.
New England	Oct. 26–27	Taft Hotel, New Haven, Conn.
Nebraska	Nov. 3–4	Castle Hotel, Omaha
South Carolina	Nov. 4	Jefferson Hotel, Columbia
North Carolina	Nov. 9–11	R. E. Lee Hotel, Winston-Salem
Florida	Nov. 13–16	Galt Ocean Mile Hotel, Fort Lauderdale
Oklahoma	Nov. 14–18	State University, Stillwater
Indiana	Nov. 16–17	Hotel Washington, Indianapolis
New York	Jan. 18–20, 1961	Park Sheraton Hotel, New York City

* See preceding left-hand page for full name.

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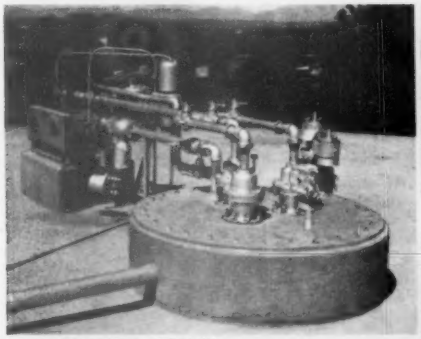

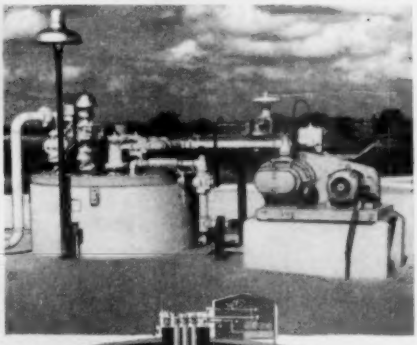

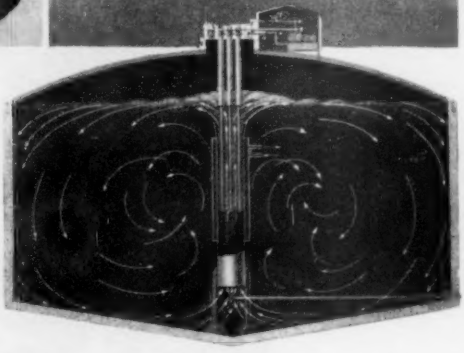

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The DIRECTUBE HEATX-GASLIFTER assembly combines economical, positive temperature control and efficient digester operation. DIRECTUBE HEATX is shop fabricated as an integral part of the GASLIFTER and requires only hot water recirculation lines from a Walker Sewage Gas Boiler. Optimum temperature requirements are easily maintained. Available with manual or automatic controls.

Write for bulletins 24-S-82 and 25-S-91.

Top Left — LAS CRUCES, N.M. — 8000 gpm GASLIFTER in 50' dia. digester with fixed cover. R. A. Smith, Supt. Gordon Herkenhoff & Assoc., Albuquerque, Cons. Engrs.

Top right — SACRAMENTO COUNTY, CALIF. (San. Dist. #3) GASLIFTER in 70' dia. digester with fixed concrete cover. Mr. Norman Farnum, Supt. Dewante & Stowell, Sacramento, Cons. Engrs.

WALKER PROCESS EQUIPMENT INC. AURORA, ILLINOIS

a leader in equipment for . . .

SEWAGE TREATMENT • WATER TREATMENT • INDUSTRIAL WASTE TREATMENT

THE MARK OF THE 100-YEAR PIPE

PERMANENTLY YOURS: CAST IRON PIPE

Installed—
it stays installed

One thing sure about cast iron pipe—once it's in the ground, it's there for keeps! Over 100 American utilities, having used cast iron pipe steadily for more than a century, can testify to that. And *modern* cast iron pipe gives you greater assurance than ever: great beam strength resists heavy surface traffic; tremendous load resistance absorbs even the most forceful pressures. In fact, when you select cast iron pipe, you can anticipate no major repairs in your water supply system for the next hundred years!

Cement-lined—it stays cement-lined

A smooth coat of cement lining along the inner wall helps prevent the formation of flow-reducing particles. No matter how strong the water is, cast iron pipe always assures a free, steady flow.

Joined—it stays joined

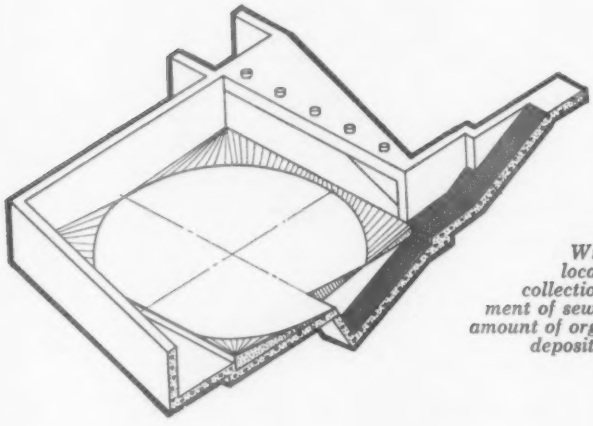
Bottle-tight, rubber-ring joints give you leak-proof protection at the most vulnerable points of your system. Vibrations, surface traffic and washouts present no problems to cast iron pipe. Inherent ruggedness . . . built to perform under all adverse underground conditions . . . repair-free service for at least a century—all good reasons why your choice should be that of water utility experts everywhere. America's greatest water carrier: cast iron pipe.

Cast Iron Pipe Research Association,
Thos. F. Wolfe, Managing Director,
3440 Prudential Plaza, Chicago 1, Ill.

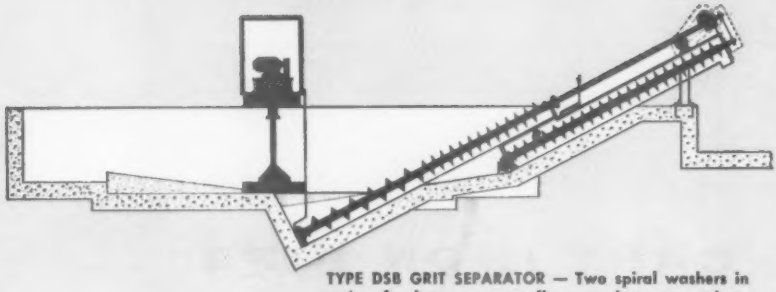
CAST IRON PIPE

GRIT SEPARATION

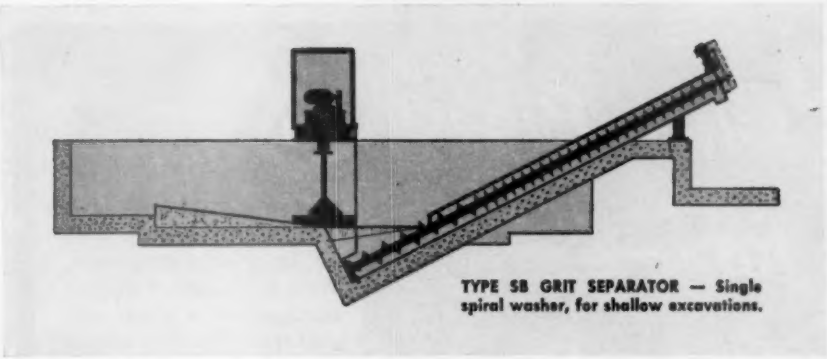
Has Never Been So Clean...



With grit pocket located inside the collection tank, movement of sewage minimizes amount of organics that can deposit in the pocket.



TYPE DSB GRIT SEPARATOR — Two spiral washers in series, for larger sewage flows or deep excavations.



TYPE SB GRIT SEPARATOR — Single spiral washer, for shallow excavations.

. . . *Since Eimco-Process Put the Washer Inside the Collection Tank!*

Dead spaces, where floating putrescibles can accumulate, have been eliminated in the new Eimco-Process Grit Separator with the spiral screw washer on the inside of the collection tank. No odor or fly nuisance. No scum hosing.

Raw sewage enters a shallow collection compartment where fast-settling solids deposit on the bottom to be scraped to a pocket directly under the path of the rotating scrapers. The pocket forms the lower end of the spiral washer trough, inside the collection tank. Sewage flowing across the pocket reduces the amount of organics that can deposit with the accumulated solids to a minimum. Washed grit is conveyed above the liquid level for easy handling.

The Eimco-Process Type SB Grit Separator for collection tanks 8 to 40 feet square has a single spiral screw washer and does not require a deep excavation.

The Type DSB for larger flows or deep collection tanks has two spiral washers in series, the lower discharging into the washer trough of the upper, as in a multi-deck washing classifier. Grit is retained and scoured in the lower end of the upper screw by interrupted spiral flights for additional removal of organics. Both spiral washers are driven by one drive unit.

Optional for both types is an automatic control that correlates the agitation in the collection compartment inversely with the flow velocity by varying the speed of the scraping mechanism. This makes possible the ultimate in cleaned grit, with the desired mesh of separation, regardless of varying flows.

The Eimco-Process representative near you will be glad to sit down with you and your consulting engineers to discuss good housekeeping in grit separation. He can also tell you about other E-P equipment of advanced design for sewage, industrial wastes and water treatment.

SEE —

Eimco Exhibit • WPCF Meeting
Convention Center • Philadelphia
October 2-6, 1960

THE EIMCO CORPORATION

Process Engineers Division
420 Peninsular Avenue
San Mateo, California

B-640E

MADISONVILLE, KY., has had no property taxes for three successive years. With this record of efficient management, it is only natural that Clay Pipe should be chosen for the city's new sewerage expansion system. More than twenty-two miles of Vitrified Clay Pipe are going into the project.

Clay Pipe was the natural choice because it does not rust, rot, corrode, or disintegrate . . . never wears out. And new, longer, stronger lengths speed installation . . . cut labor costs.

Only Clay Pipe has *all* the features you can trust.

Public Officials: David Parish, Mayor; A. O. Johnston, Councilman, Chairman of Water and Sewers.

Consulting Engineers: J. Sanders Parker; F. E. Stepp, Resident Engineer.

Contractors: C.F.W. Construction Co., Inc.; Sterrett Construction Co.

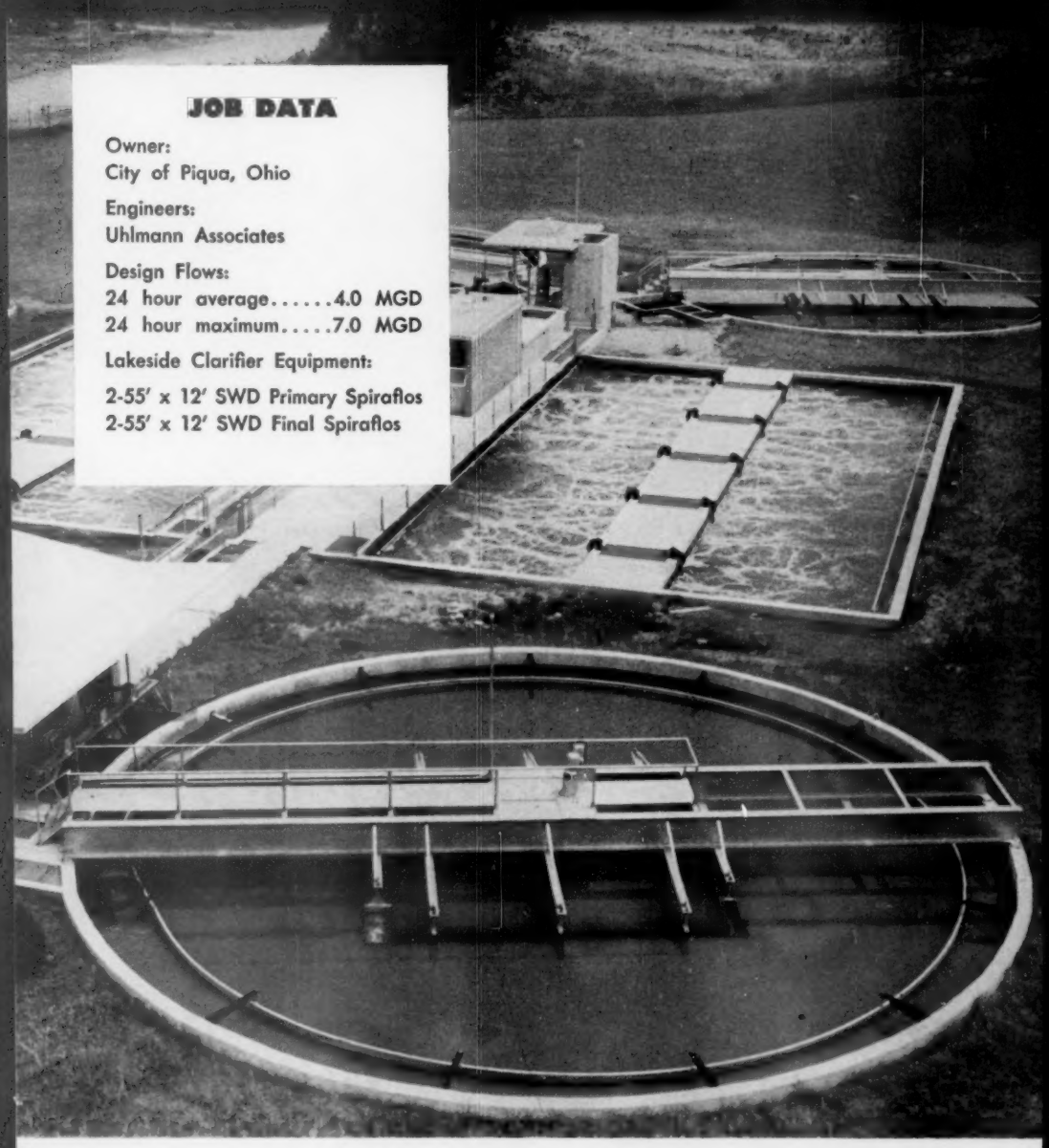
C-458-1A

Vitrified **CLAY PIPE** *Never Wears Out*

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1820 N St. N. W., Washington 6, D. C.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio • 445 Ninth St., San Francisco 3, Calif.
Box 172, Barrington, Illinois • 1401 Peachtree St., N. E., Atlanta 9, Georgia



JOB DATA

Owner:
City of Piqua, Ohio

Engineers:
Uhlmann Associates

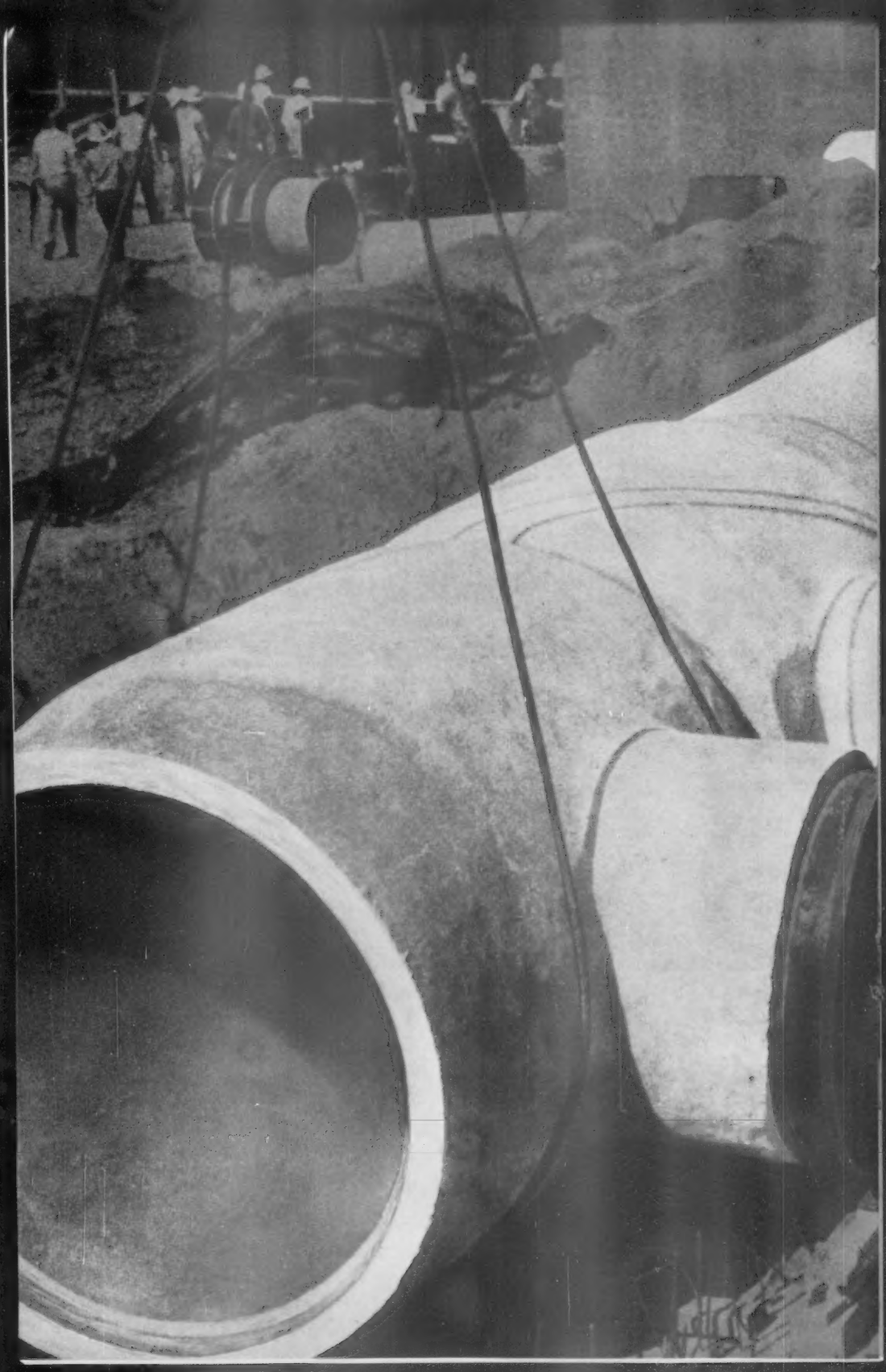
Design Flows:
24 hour average.....4.0 MGD
24 hour maximum.....7.0 MGD

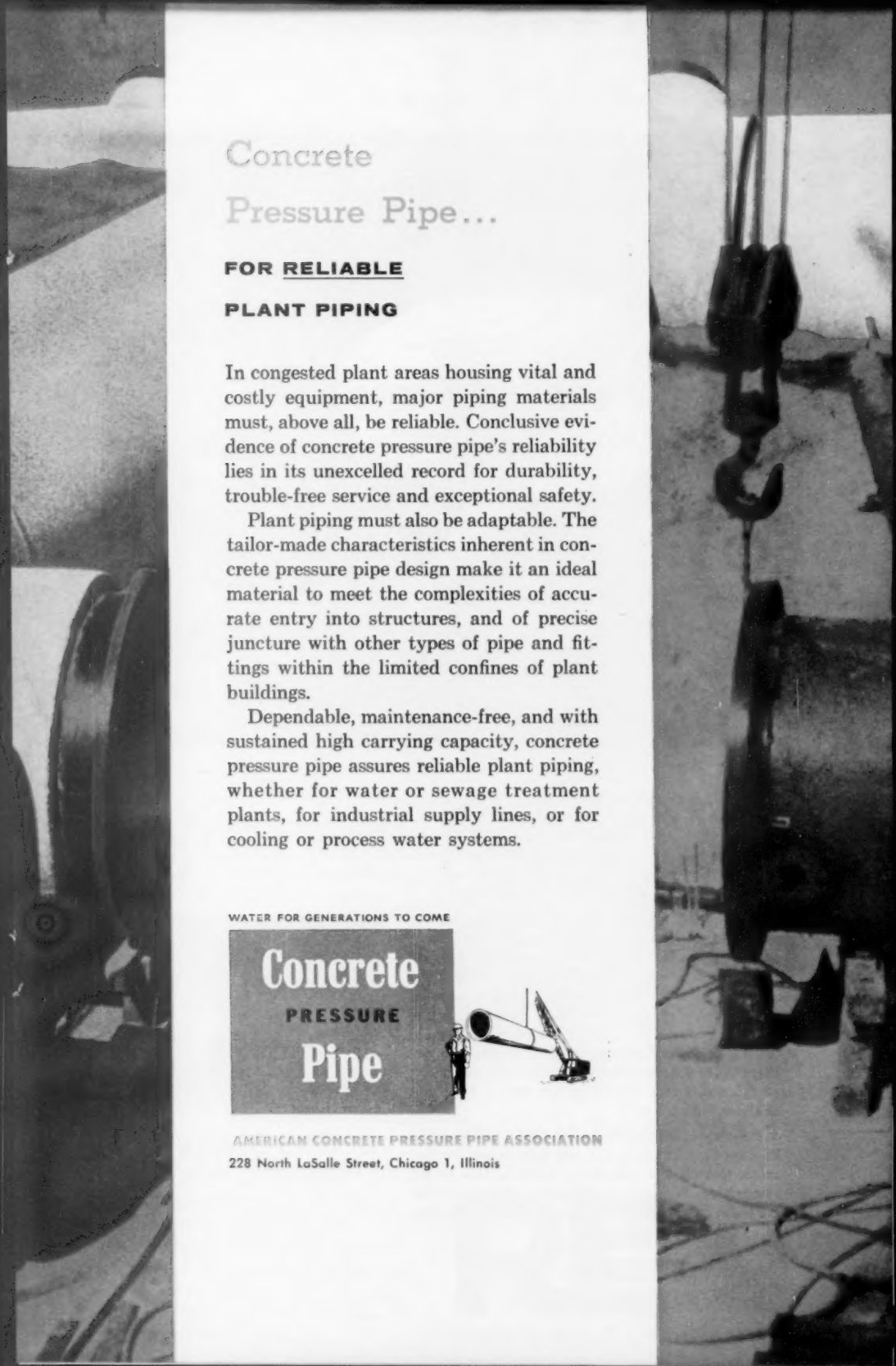
Lakeside Clarifier Equipment:

2-55′ x 12′ SWD Primary Spiraflos
2-55′ x 12′ SWD Final Spiraflos

SPIRAFLOS—give high removals as both primary and final settling tanks—ideal as finals on activated sludge because of the added depth and the flow pattern that traps the light activated particles in the sludge blanket build up. Also a perfect clarifier for the smaller plants particularly where efficient skimming and scum removal are desired.

LAKESIDE
ENGINEERING CORPORATION
222 West Adams St. Chicago 6, Illinois





Concrete Pressure Pipe...

FOR RELIABLE PLANT PIPING

In congested plant areas housing vital and costly equipment, major piping materials must, above all, be reliable. Conclusive evidence of concrete pressure pipe's reliability lies in its unexcelled record for durability, trouble-free service and exceptional safety.

Plant piping must also be adaptable. The tailor-made characteristics inherent in concrete pressure pipe design make it an ideal material to meet the complexities of accurate entry into structures, and of precise juncture with other types of pipe and fittings within the limited confines of plant buildings.

Dependable, maintenance-free, and with sustained high carrying capacity, concrete pressure pipe assures reliable plant piping, whether for water or sewage treatment plants, for industrial supply lines, or for cooling or process water systems.

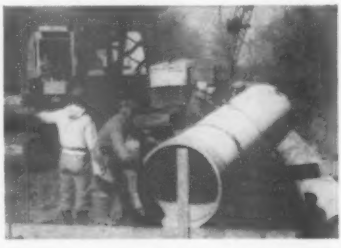
WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street, Chicago 1, Illinois

Right! There's no rodding necessary because roots just can't get in and clog up Transite®, *the white sewer pipe*. Johns-Manville's patented Ring-Tite® Joint keeps out even the thirstiest of these system disrupters. And it remains impenetrable for the duration of the line. Remember, by keeping roots out you eliminate the major cause of expensive periodic cleanouts . . . an expense which can run over $2,000 annually per mile of pipe in a system having joints that are not tight.

Actually, Transite starts saving you money from the very beginning. Its long length and light weight make this asbestos-cement pipe easy to handle in trucking, moving and lowering into the trench. Once in the trench, Transite adjusts easily and speedily to accurate line and grade. And that Ring-Tite coupling makes a dependable joint quickly and effortlessly. You'll save on operation costs too, because Transite's low coefficient of friction ($n = 0.010$) means faster flow and shallower trenches.



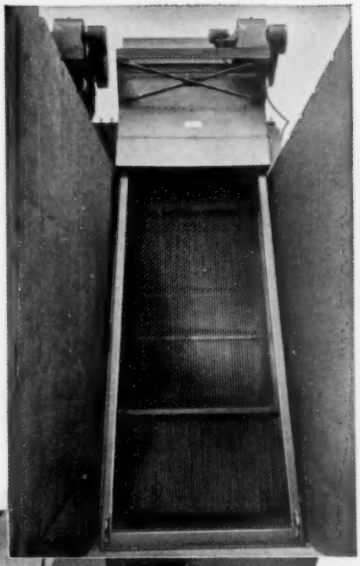
Hartley knows what he's talking about when he says that Transite can cut *your* sewer system costs. Get all the details on Transite, the white sewer pipe. Write Johns-Manville, Box 14, JW-2, New York 16, N. Y. In Canada: Port Credit, Ont.

JOHNS-MANVILLE
TRANSITE PIPE

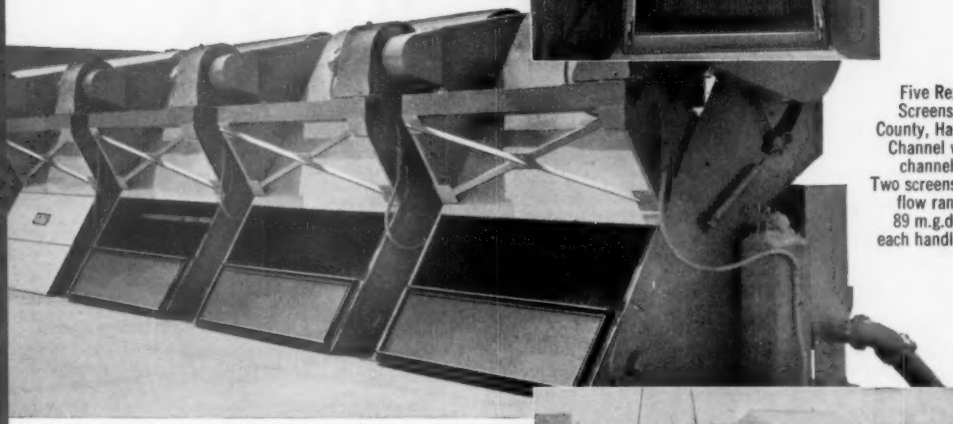
Rex PIVOTED Bar Screens

Provide Maximum Flexibility for Los Angeles County Plant

In the Los Angeles County Sanitation District No. 2 Sewage Treatment Plant at Harbor City, a new concept in screening operations has assured a new high in efficiency and flexibility... a new low in operating and maintenance costs... REX PIVOTED BAR SCREENS.

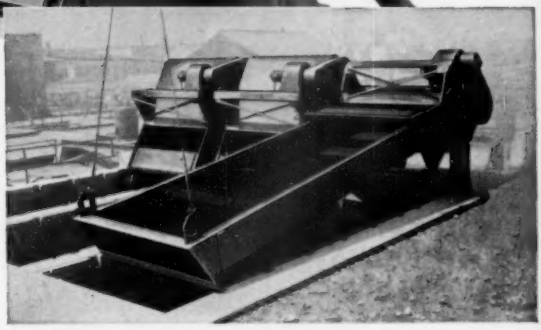


Close-up view showing screen suspended in channel. Note neat appearance... totally enclosed, streamlined housing and "straight-through," unobstructed flow.



Five Rex PIVOTED Bar Screens at Los Angeles County, Harbor City Plant. Channel width, 6½ feet; channel depth, 16 feet. Two screens each handle a flow ranging from 30 to 89 m.g.d. Three screens each handle flows of 42 to 127 m.g.d.

With this advanced design, each screen is pivoted so that it can be easily swung out of the channel for inspection and servicing. No need to dewater the channel... no need to shut down operations. Screens are back in service in a hurry.



Screen pivoted out of channel. Pivot shaft rides in heavy-duty angle pillow blocks mounted on concrete pedestals.

FRONT CLEANING... front-mounted rake is held firmly in place... provides maximum shelf for carrying capacity. Positive, complete cleaning of tops and sides of bars to their full depth. Rakes *and* teeth clean the bars. No chance for rakes to slide over, or miss, screenings. Bar rack is held firmly in place at top and bottom to maintain uniform spacing.

MAXIMUM EFFICIENCY. Full 60-degree inclined racks mean greater rack area exposed to the flow. Dead plate from bar rack to point of discharge eliminates spillage... no screenings on downstream side. Chain Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wis.

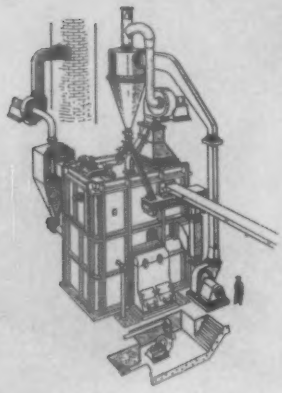
See us at Booths 206–208

REX®

CHAIN BELT COMPANY

WASTE DISPOSAL HAS COST RECOVERY POSSIBILITIES

Why not explore them for your community?



FOR SLUDGE DISPOSAL

THE C-E RAYMOND FLASH DRYING AND INCINERATION SYSTEM

is the only system that permits both drying and incineration of sewage sludge — separately or together — in any proportion. This service-proved equipment today processes more filter cake than all other systems combined. High temperature deodorization and efficient fly ash collecting equipment assure that nearby residents are not bothered by air pollution. The C-E Raymond System's unique design and control also assure economy of operation and uniformity of product.

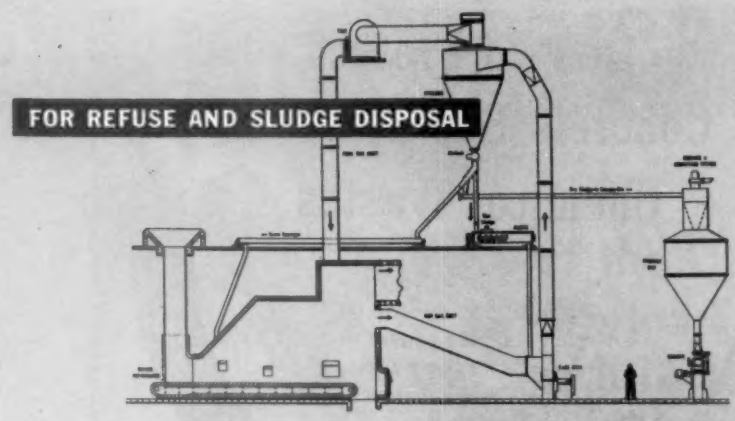
COMBUSTION

Combustion Engineering Building

Raymond Division: 1132 West Blackhawk Street, Chicago 22, Ill.

Canada: Combustion Engineering-Superheater Ltd.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;



THE C-E INCINERATOR STOKER AND THE C-E RAYMOND SYSTEM

combine a half-century of experience in burning all kinds of conventional, marginal and waste fuels with the most service-proved drying system. Using "continuous" processing, the C-E Incinerator Stoker requires only minimum operating attention and maintenance. From the time refuse is fed into the self-sealing, non-clogging hopper, until the incinerated residue is discharged to the ash pit to be hauled away, the entire operation is automatic, efficient, quick and clean. The C-E Incinerator Stoker is capable of burning all types of combustible refuse in quantities ranging upward from 50 tons per 24-hour day. Heat from the burning refuse is used by the C-E Raymond Flash Dryer System to dry sewage sludge.

Yes, even waste disposal can be turned into a *productive* function. Municipalities all over the country find new economies . . . new revenues . . . through their use of Combustion units like those shown on these pages. With continuous, near-automatic processing, substantial manpower can be diverted to other duties . . . capacity per dollar of investment is increased . . . usable and marketable end-products are produced.

Many communities turn sewage sludge into a desirable, humus-rich soil conditioner with the C-E Raymond Flash Drying and Incineration System. Often, they can recover a large part of their operating expenses from sale of this conditioner or use it to maintain parks and recreation areas. Other towns use units of the same design to incinerate sludge to sterile ash. These versatile units can produce one or both end-products in any proportion.

For refuse incineration, the C-E Traveling Grate Incinerator Stoker is available. It reduces garbage and refuse to a sterile ash, free from clinkers. The ash is suitable for use as a sanitary land fill for the reclamation of waste land. Where required, the incinerator may be used in conjunction with a C-E Waste Heat Boiler to provide an economical steam source for plant heating or power.

To make the most of existing property, economy-minded municipalities are looking more and more into the possibility of *treating both refuse and sewage sludge* at the same plant site. Aside from the obvious benefit of lower capital investment, there's the added benefit of being able to combine both manpower and equipment, eliminating costly duplication. In addition, the C-E Refuse Incinerator can readily supply *no-cost heat* to dry the entire output of sewage sludge.

ENGINEERING

200 Madison Avenue, New York 16, N. Y.

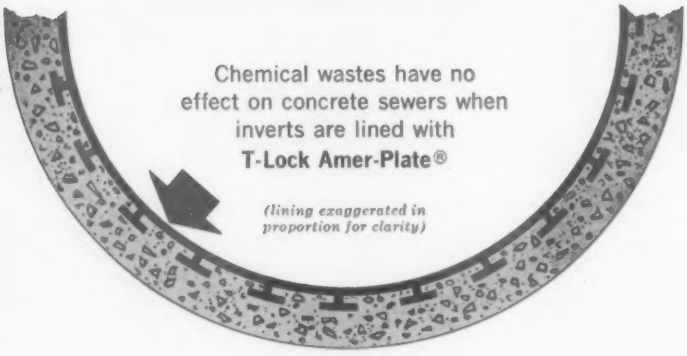
Western Office: 510 West Sixth Street, Los Angeles 14, Calif.

C-E

C-215-A

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

How to Protect Concrete Sewers from Chemical Wastes


Chemical wastes have no effect on concrete sewers when inverts are lined with
T-Lock Amer-Plate®
(lining exaggerated in proportion for clarity)

T-Lock Amer-Plate is a high polymer PVC sheet, easily cast into pipes, tunnels and structures to form a partial or complete 360° protective lining. Used in inverts, it permanently protects concrete from corrosive chemical effluents. In arch areas, it positively stops oxidized H_2S corrosion. T-Lock is also highly abrasion resistant; impartial tests show that it abrades at only 1/70th the rate of concrete.

The fact that T-Lock ends erosion and corrosion problems in industrial and municipal sewer systems is attested to by more than five million square feet now in use. Write for complete data on this maintenance-saving lining before designing your next sewer.

Applicators strategically located throughout U. S. and Canada

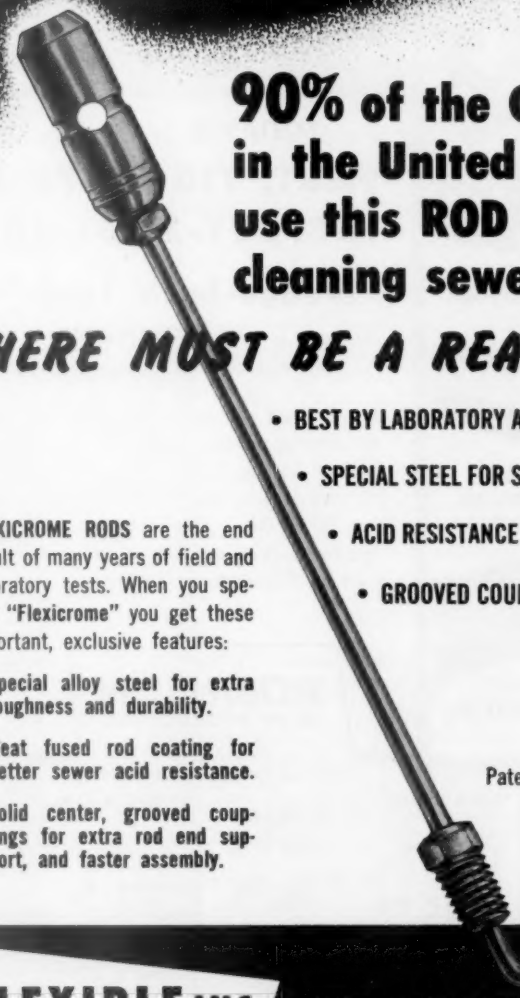
Amercoat® CORPORATION

Dept. SI • 4809 Firestone Boulevard • South Gate, California

921 Pitner Ave. Evanston, Ill. | 360 Carnegie Ave. Kenilworth, N.J. | 2404 Dennis St. Jacksonville, Fla. | 6530 Supply Row Houston, Texas | 111 Colgate Buffalo, N.Y.

118

FLEXICROME



90% of the Cities in the United States use this ROD for cleaning sewers . . .

THERE MUST BE A REASON!

- BEST BY LABORATORY AND FIELD TEST
- SPECIAL STEEL FOR SEWER RODDING
- ACID RESISTANCE TREATED
- GROOVED COUPLINGS

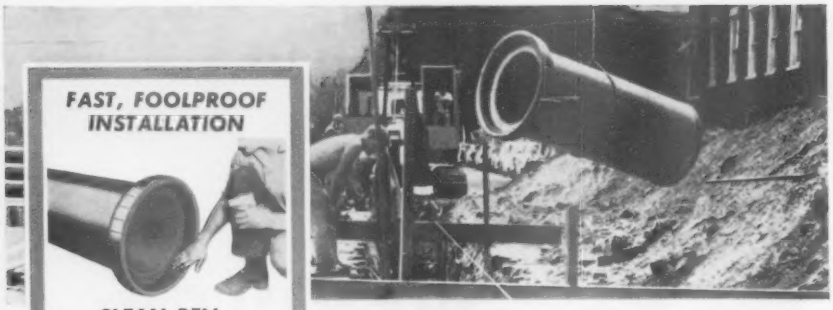
FLEXICROME RODS are the end result of many years of field and laboratory tests. When you specify **"Flexicrome"** you get these important, exclusive features:

* **Special alloy steel for extra toughness and durability.**
* **Heat fused rod coating for better sewer acid resistance.**
* **Solid center, grooved couplings for extra rod end support, and faster assembly.**

Patent No. 2,471,060

FLEXIBLE INC.

3786 Durango Ave. • Los Angeles 34, Calif.
LIMA, OHIO DALLAS, TEXAS



FAST, FOOLPROOF INSTALLATION

CLEAN BELL

CLEAN SPIGOT

PLACE RUBBER "O" RING IN SPIGOT GROOVE

LINE UP, SHOVE INTO PLACE THAT'S ALL THERE IS TO IT!

TODAY'S

FAST, TIGHT, TOUGH FACTORY-MADE JOINT

Wedge-Lock* Type "O"

BY ROBINSON

Now Available In Diameters Through 36"

Now, lines go in faster, seal tighter, stay trouble-free longer. Robinson Type "O" joints reduce laying time . . . cut installation costs . . . are ideally suited to difficult installation conditions. New precision-tight Factory-Made Wedge-Lock Type "O" joints handle infiltration and roots in any terrain.

THE ROBINSON CLAY PRODUCT CO.
ESTABLISHED 1856
AKRON 9, OHIO

*Patented. T.M. Reg. U.S. Pat. Off.

FASTER SERVICE

You get quick delivery of all sizes from strategically located Robinson branches.

FOR MORE DETAILS

on Robinson Factory-Jointed Clay Pipe, Call the Robinson Branch Office nearest you.

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65 W. State St. POrtage 2-8601

ALBANY 4, N. Y.
1357 Broadway HObart 3-4139

BALTIMORE 2, MD.
1546 Mathieson Bldg. MUlberry 5-2930

BOSTON 34, MASS.
22 Pratt St., Allston Station STadium 2-8900

BUFFALO 10, N. Y.
1146 Seneca St. TRiangle 3082

CALDWELL TOWNSHIP, N. J.
Kulick Road (off Fairfield Road) CApital 6-8800

CHICAGO 46, ILL.
7100 N. Lehigh Ave., Edgebrook Sta. NEw Castle 1-5700

EAST HARTFORD 8, CONN.
170 Tolland St. BUtler 9-4389

INDIANAPOLIS 7, IND.
1013-15 E. 21st St. WAlnut 3-1507

NEW YORK, N. Y.
107-10 180th St., P. O. Box 589 Jamaica, L. I., N. Y. REpublic 9-7100

PHILADELPHIA, PA.
P. O. Box 85, Pottstown, Pa. FAculty 6-1310

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SYRACUSE 3, N. Y.
534 Spencer St. HArrison 2-9226

TORONTO, ONTARIO, CANADA
Baldwin Ave., Concord, Ontario, Canada AVenue 5-1138

YONKERS, Westchester County, N. Y.
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R-660 139

This is the chlorinator you can be proud of. Its handsome modern appearance reflects the advanced technology of its working parts. It is the first chlorinator ever to offer a complete regulator system in a single stack. There is no frail piping. Not even traces of moisture can feed back from the ejector. Any vacuum interruption stops operation . . . instantly closes the chlorine inlet valve. We believe it to be—inherently—the safest, most dependable, and most accurate chlorinator ever devised. It is also the most controllable. Automatic models accept any imaginable type of signal, use it to feed up to 2000 pounds per day of chlorine according to any control mode you may choose. Because of its advanced design, because of its corrosion-proof construction, we firmly believe that this is the chlorinator that will never—never—grow old.

If you choose to buy one of these chlorinators sight unseen, on our say-so, we can deliver immediately from warehouse stocks across the country. If not, your local F&P field office will be happy to demonstrate the 3400 Series at your plant, at your convenience. Call for an appointment. Or, write for complete information in Catalog 70C3400. Fischer & Porter Company, 1150 Fischer Road, Warminster, Pa.

FP

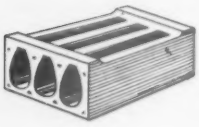
FISCHER & PORTER COMPANY

INSTRUMENTATION AND CHLORINATION

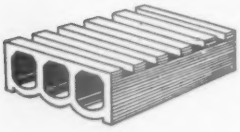
These MANUFACTURING AFFILIATES carry Fischer & Porter engineering designs to the far corners of the earth: FISCHER & PORTER (CANADA) LTD., DOWNSVIEW, ONTARIO • FISCHER & PORTER LTD., WORKINGTON, CUMBERLAND, ENGLAND • FISCHER & PORTER G.m.b.H., GROSSELLERSHAUSEN, BEI GOTTINGEN, GERMANY • FISCHER & PORTER N.V., KOMEETWEG 11, THE HAGUE, NETHERLANDS • FISCHER & PORTER Pty. LTD., 1457 MALVERN ROAD, TOORONGA, S.E. 6, VICTORIA, AUSTRALIA.

Turn a Liability into an ASSET!

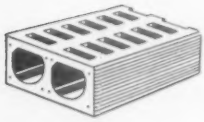
Polluted waters are a liability that progressive communities can no longer afford. Clean them up with trickling filters for sewage and industrial wastes as over 1,000 others have done since 1945.



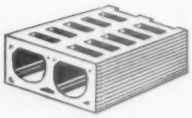
NATCO
Natco Corporation
Pittsburgh 22, Pa.



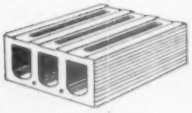
TRANSLOT
Connelton Sewer Pipe Co.
Connelton, Ind.



ARMCRE
Ayer-McCarel Clay Co., Inc.
Brazil, Ind.



BOSCO
Bowerston Shale Co.
Bowerston, Ohio



POMONA
Pomona Terra-Cotta Co.
Pomona, No. Car.

The most vital part of a trickling filter is its underdrain system. When it is of TFFI specifications vitrified clay blocks life-time, trouble-free service is assured. Specify in accordance with ASTM Specifications C 159-59T and demand that they be adhered to and you are safe for years to come.

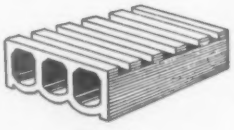
Copies of these Specifications are included in the new TFFI Handbook and may be had from the nearest member listed if you lack yours.

These vitrified clay underdrain blocks for filter floors resist acids, alkalis, bacteriological action and other corrosive factors. They are made in modern plants under manufacturing controls that substitute materials cannot even approach.

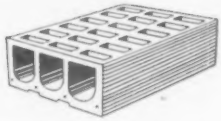
DEMAND CERTIFIED UNDERDRAIN BLOCK

Vitrified Clay Block manufactured by TRICKLING FILTER FLOOR INSTITUTE members and tested by the Materials Testing Laboratory of Rose Polytechnic Institute comply with or exceed ASTM Specification C 159-59T.

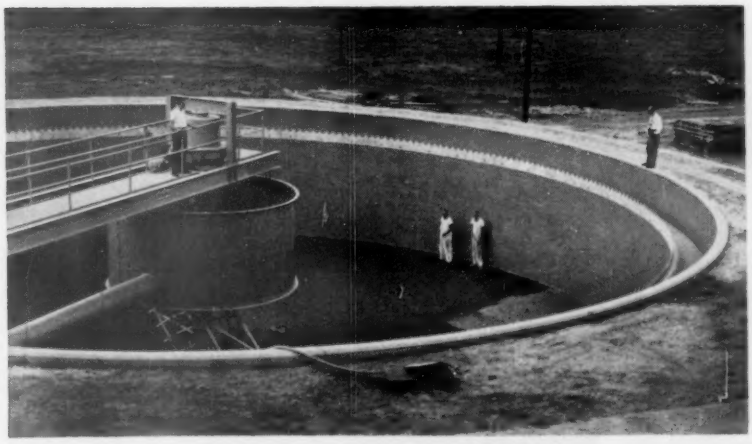
TRICKLING FILTER FLOOR INSTITUTE



TRANSLOT
Texas Vitrified Pipe Co.
Mineral Wells, Texas



DICKEY
W. S. Dickey Clay Mfg. Co.
Kansas City 6, Mo.

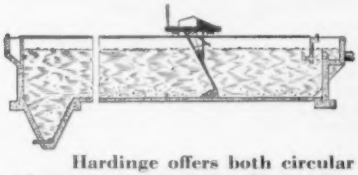


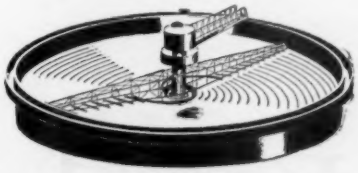
PAPER MILL INSTALLS SECOND HARDINGE CLARIFIER FOR WASTE TREATMENT

The P. H. Glatfelter Company, paper manufacturers at Spring Grove, Pa., have gone a step farther in keeping wastes from its manufacturing processes out of the nearby Codorus creek. Recently, a $100,000 addition to its waste treatment plant was put into operation. It is a twin to a Hardinge Clarifier that has been in use for a number of years. Besides doubling the mill's waste treatment capacity, it helps to remove more solids from the main effluent flow.

Each clarifier is 75 feet in diameter and 15 feet deep. Together they hold nearly a million gallons and provide two hours' settling time for the main effluent on its way to the Codorus.

The main waste from the mill is pumped to the clarifier. The clarifier removes fiber and clay residues from paper processing waters. The average amount taken out of the waste amounts to from 10 to 15 tons a day.





Hardinge offers both circular and rectangular-tank clarifier mechanisms, as well as complete water-treating systems. Ask for Bulletin 35-D-16.

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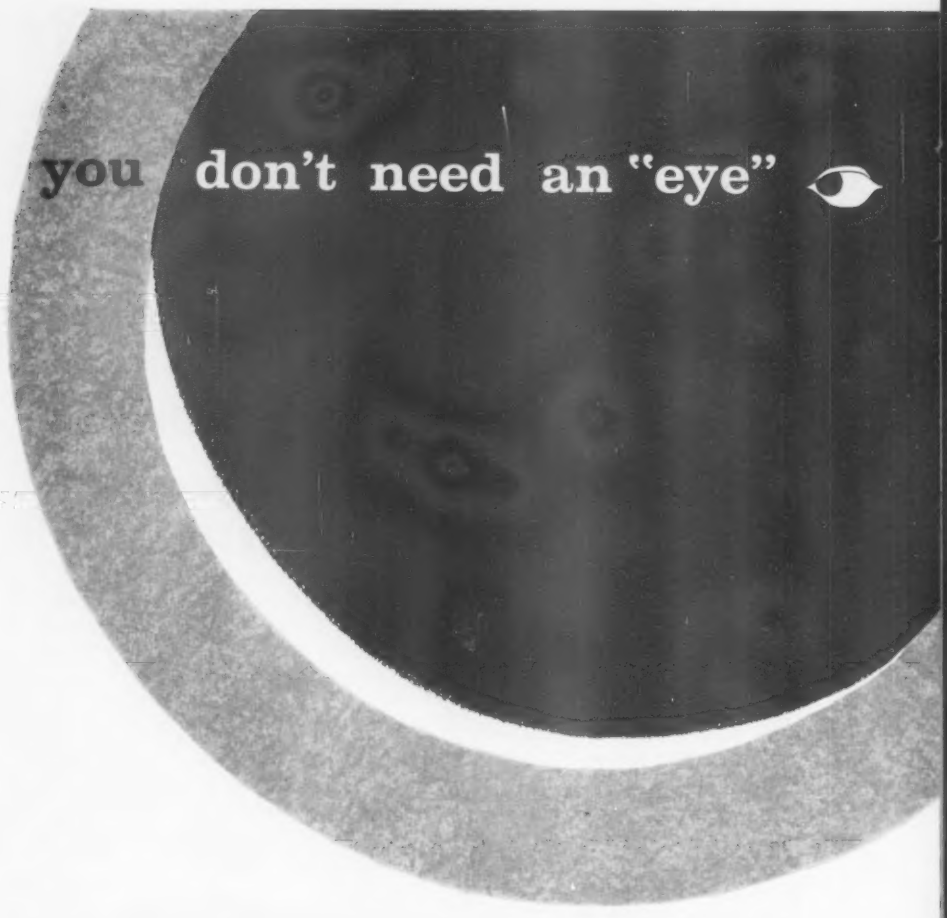

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SEWER PIPE

"K&M" Asbestos-Cement Sewer Pipe helps you provide the best sewer service available . . . with tax savings that go on year after year.

This thrifty pipe is infiltration-proof, even when external water pressure is 25 psi. Prevents your sewer system from reaching full capacity years ahead of schedule, due to water infiltration. "K&M" Asbestos-Cement Sewer Pipe, with exclusive, patented FLUID-TITE Coupling, forms a permanently tight seal.

In planning your system, you can build on flatter grades with "K&M" Asbestos-Cement Sewer Pipe. Need fewer lift stations. The permanently smooth bore of "K&M" Asbestos-Cement Sewer Pipe has a Manning factor of n=0.010. Flow characteristics are excellent. Inspections and treatment loads become less frequent.

This thriftiness carries over into installation. Neither weather nor soil conditions need hold up work. The "K&M" FLUID-TITE Coupling slides on in just two easy steps. Longer pipe lengths minimize the number of joints.

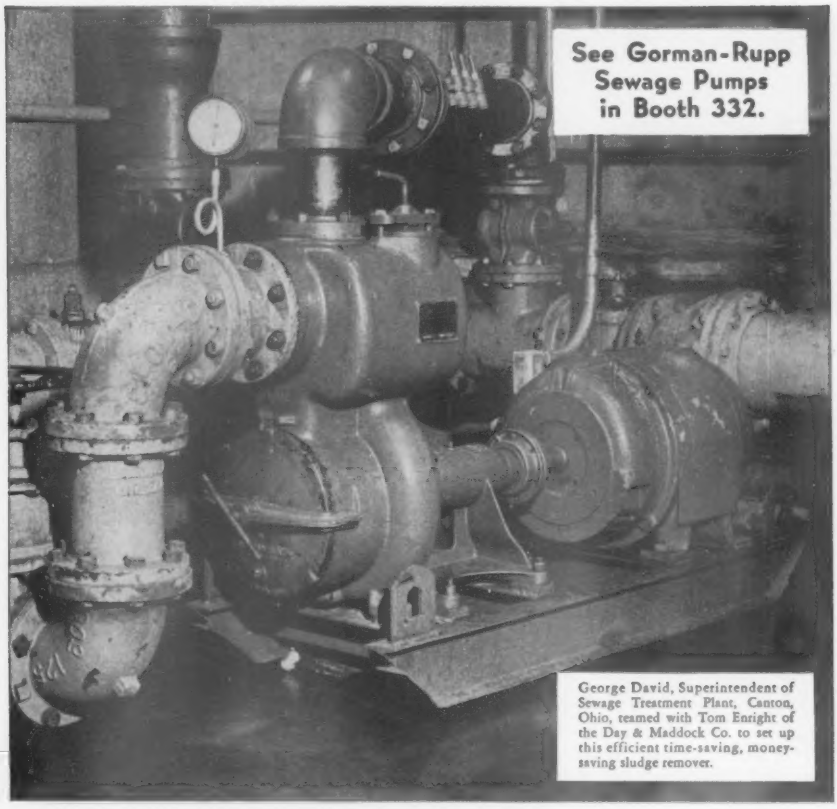
Write today for more detailed and illustrated information on hardy "K&M" Asbestos-Cement Sewer Pipe. Learn why thousands of progressive communities have turned to this durable quality pipe. Write to: Keasbey & Mattison Company, Ambler, Pa., Dept. P-1790.

son at Ambler

K·M BEST IN ASBESTOS

Easy installation! Couplings join quickly. No heavyweight coupling pullers needed.

"K&M" PLASTIC SEWER PIPE complements "K&M" Asbestos-Cement Sewer Pipe in many sewer systems. Excellent flow characteristics and permanently tight joints. Write for Technical Bulletins on "K&M" High-Impact Styrene-Alloy Sewer Pipe. Dept. P-1790.



George David, Superintendent of Sewage Treatment Plant, Canton, Ohio, teamed with Tom Enright of the Day & Maddock Co. to set up this efficient time-saving, money-saving sludge remover.

Recirculation and Cleaning Pump solves Canton Digester Problem

Gorman-Rupp Sewage Pump cleans with no downtime and major savings

Problem—To remove 7-years' accumulation of sludge from 10 huge digesters. With mechanical shoveling devices, it cost $5000 to clean only one digester. And during cleaning, digester was totally inoperative for 6 weeks.

Answer—A Gorman-Rupp Model 16A2-B Pump. Its unique action first agitates sludge into a common mixture by circulating digester liquid under pressure. Then, with valves reversed, pump draws off liquid and suspended solids for disposal.

Result—Each digester could be cleaned in only 21 days. Only outlay is cost of 6″ pump, electric motor, and labor of opening and closing 2 valves twice a day.

4″ and 6″ pumps can be connected to your power or ordered complete with power units. Write for complete specifications.

Fast Action End Plate. Releases for access to impeller and renewable wear plate. Impeller is 2-vane trash type that handles spherical solids up to 2½″ in diameter.

THE GORMAN-RUPP COMPANY
305 Bowman Street • Mansfield, Ohio
Gorman-Rupp of Canada, Ltd.,
St. Thomas, Ontario

NOW

SONOCO

P.I.

PITCH-IMPREGNATED

PIPE

economical FIBRE PIPE for large diameter waste disposal lines

Now, the advantages of fibre pipe can be had in large diameter low-pressure lines with SONOCO P.I. PIPE — the first and only fibre pipe available in I.D.'s up to 36 inches!

This low-cost fibre pipe is particularly valuable in industrial waste disposal systems, because it withstands the attacks of chemical effluents and requires no mastic coating or other special treatment. Designed primarily for gravity flow lines where the maximum head does not exceed 20 feet, P.I. PIPE combines high corrosion resistance with strength, light weight, ease of installation, and great versatility in use.

For low-pressure gravity flow lines

•

For industrial venting

P.I. PIPE comes in 10' lengths up to 36" I.D.; straight line fibre couplings available with or without neoprene gaskets. Can be sawed, or drilled and tapped for special fittings. Steel fittings may be connected to P.I. PIPE with Dresser or other similar couplings.

LAMINATED FOR LASTING DURABILITY

P.I. PIPE is composed of many layers of tough fibre, tightly bonded together for greater strength, then impregnated with liquefied coal tar pitch to make it impervious to most types of chemical corrosive agents. Properly installed above or below grade, or underwater, P.I. PIPE will withstand thermal shock, traffic tremors, and soil settlement without rupturing or cracking.

On each order of P.I. PIPE wall thickness can be varied in any given I.D., to meet exact crushing strength requirements. This means a better, more economical installation.

For complete information and prices, write

SONOCO

Construction Products

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SONOCO PRODUCTS COMPANY • HARTSVILLE, S. C.

Tremendous Savings Quickly Pay for an

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SLUDGE DENSITY CONTROL SYSTEM

Savings of thousands of dollars are reported in the operation of sewage treatment plants after installation of the Ohmart Nuclear System for accurate and automatic control of sludge density.

Check these important benefits which an Ohmart Density Control System has brought to plant after plant:

Increased digester capacity and efficiency without additional equipment—fuel requirements reduced by one-third—reduction in thickness requirements and odor problems—less liquid is pumped—less heat required—lower fuel costs—pumps require less horsepower—blockages are detected sooner.

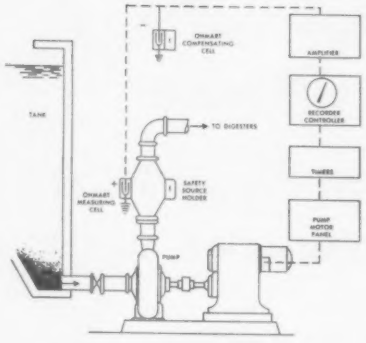

Diagram shows components of Ohmart Sludge Density Control System at Los Angeles County Sanitation District's Joint Disposal Plant

Ohmart Density Gages are invaluable components of any process where close-limit control of the density of liquids, slurries, or dry solids will mean substantial dollar savings. These gages employ a gamma radiation source and the patented Ohmart cell which converts gamma radiation directly into electrical energy for density measurement and control. No moving parts; no contact with media; nothing to wear out, plug or corrode.

You cannot lose by installing Ohmart, as satisfactory performance is guaranteed. Write for descriptive bulletin SDL, or ask for an Ohmart field engineer to call.

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The Ohmart Corporation
2234 Bogen St., Cincinnati 22, Ohio
World Leader in Nuclear Process Control

Engineering representatives in principal areas

clean, safe
WATER
for generations to come

Our nation's population growth requires water—clean water, and lots of it! Controlling pollution of lakes, streams and rivers means better public health and water supplies, new and improved vacationlands abounding in fish and wildlife. Local industries also benefit from unpolluted water supplies. Up-to-date sewage treatment facilities insure these continuing benefits. The following cases show actual benefits achieved by planned water pollution control.

Everybody benefits from clean water

Abundant usable water is every American's birthright—and responsibility! Modern living takes good water away...modern technology alone can restore it.

Clean, sparkling river water flowing into Wyoming's Glendo Reservoir makes it a great place for water sports!

The Glendo Reservoir on the North Platte River was ideal for recreation except for the untreated sewage being poured into the river by every town for 100 miles upstream. Then they all joined in a highly successful clean-up campaign. Ridding the river of dangerous wastes not only took care of a serious public health problem—it gave everyone a delightful new recreation attraction after the dam was built. Boating, swimming and fishing bring many vacationers to the area each year.

"They're catching bass in the Walnut River for the first time in 35 years!" say local fishermen. Oil field, refinery and municipal wastes spoiled one of the prettiest rivers in southern Kansas. But the communities and industries along the Walnut River set up a *pollution abatement program* and each cooperated to carry it out. They've built new sewage treatment plants, eliminated oil field brines and set up waste treatment facilities at refineries. The river is being returned to its original beauty—a natural resource to be proud of!

"Our water clean-up brought us new industry and jobs," says Mayor J. E. Keech, Cumberland, Maryland. The city built a new sewage treatment plant (above) that will take care of all home and factory wastes, even with the growth expected in the next ten years. And that's one important reason Pittsburgh Plate Glass Company came to Cumberland! Their new factory will bring jobs for nearly a thousand people.

Right next door to luxury homesites . . . treatment plant doubles as popular marina!

An attractive and useful asset to the community is the sewage treatment plant at Clearwater, Florida. Its appearance would do credit to a fine yacht club. There are 45 boat slips for public use at the Marina Station. Planned for the future, the plant's capacity for treating wastes will be more than adequate for the population expected when the area is fully developed.

Treatment plant on a boulevard wins favor for engineers and city officials

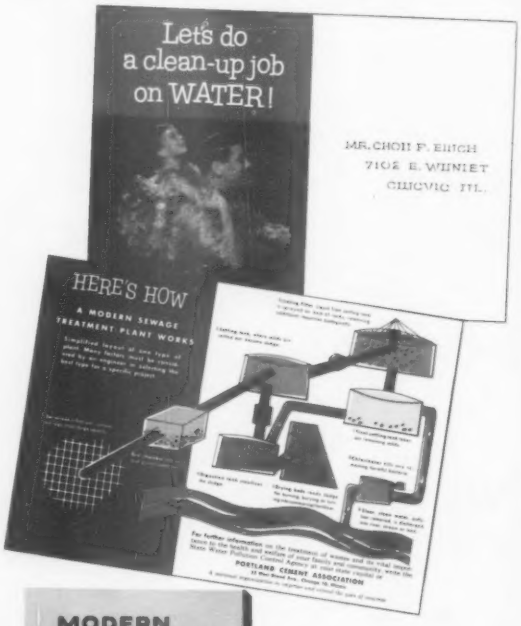
The Coral Gables, Florida, sewage treatment plant is truly a civic showplace. Walls are decorated with colorful scenes by famous artist John St. John. A well-designed, odor-free treatment plant is a credit to a community wherever it's located!

HERE'S HELP IN GETTING PUBLIC SUPPORT FOR ACTION ON POLLUTION PROBLEMS IN YOUR AREA

The pages you have just read relate a story that needs telling to the public. That's why PCA is reprinting this colorful insert—with a new fourth page—folded for easy mailing (shown at right.)

This mailing piece is available in quantity for use locally where help is needed to inform the public as to the urgency for obtaining adequate pollution control facilities.

For further information about this folder, or for help of any kind in planning your clean-up programs—just call on PCA.



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MODERN concrete

A national organization to improve and extend the uses of concrete

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As one of America's primary producers of aluminum sulfate, General Chemical has established a network of strategically located plants from coast to coast. Those listed above can provide you with a close, convenient source of supply. These modern plants are located in the heart of active consuming areas. They facilitate service to you. They save transportation costs. In addition, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available everywhere. Write or phone today for further information on how these facilities can be put to work for you.

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GENERAL CHEMICAL DIVISION
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Weir plates of Everdur control water flow in Toronto's new Humber plant

These corrosion-resistant Everdur weir plates will handle 50 *million gallons* of water every day at the new Humber sewage treatment plant.

Easy fabrication. Everdur weir plates are being joined by arc welding prior to installation.

EVERDUR RESISTS CORROSION. Installations of Everdur sewage-treatment and waterworks equipment in the United States have been in service without replacement for 30 years and longer.

EVERDUR IS TOUGH. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.

EVERDUR IS READILY FABRICATED. Everdur alloys are available for hot or cold working, welding, free machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

WRITE FOR PUBLICATION E-11—or for assistance from the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5996

EVERDUR® Anaconda's Family of Copper-Silicon Alloys
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STRONG • WELDABLE • WORKABLE • CORROSION-RESISTANT

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☐ No. 6661 ☐ No. 4007 ☐ No. 6250-R ☐ No. 300 ☐ No. 4408 ☐ No. 102 ☐ No. 6751 ☐ No. 6770 ☐ No. 6505

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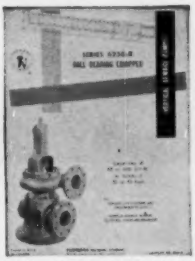
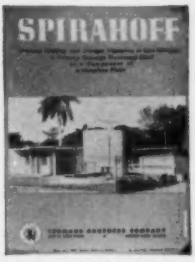
HI-CONE® Surface Aeration Waste Treatment System, **No. 6661**

SHONE® Pneumatic Ejectors, Mechanically Controlled, **No. 4007**



VERTICAL SEWAGE PUMPS, Centrifugal Type, **No. 6250-R**

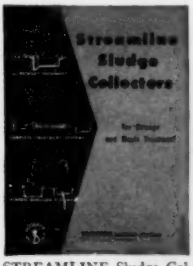


SPIRAHOFF® System, Primary Settling and Sludge Digest., **No. 300**

EXPELSOR® Pneumatic Ejectors, **No. 4408**

NEW

CAVITATOR® Aerator Waste Treatment System, **No. 102**



STREAMLINE Sludge Collectors, Conveyor Type, **No. 6751**

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PACKAGE Sewage Treatment Systems, **No. 6770**

ROTARY DISTRIBUTORS for Trickling Filters, **No. 6505**

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No weather problems this winter —if you plan now...

PASS PIPE THROUGH PIPE UNDERGROUND

with Inner Circles

PRECAST REINFORCED CONCRETE TUNNEL PIPE

Worker guides an oval-shaped section of Inner Circles pipe which the Tunnelugger has carried through the conduit already laid.

Avoid the hampering effects of winter weather on outdoor construction by *working underground. Plan now* to utilize the Inner-Circles Method of building new sewers (left) and relining failing sewers (above) *this winter.*

Extensive surface excavation and back-fill eliminated • Reduced equipment and labor • Faster completion at *lower cost* • Overhead traffic undisturbed • Improved hydraulics • Pretested pipe strengths • Tight joints—even on sharp curves • Installation equipment furnished.

The two-way Tunnelugger can operate in either direction from a centrally operated shaft—quickly delivering and positioning elliptical sections through conduit already laid.

Inner Circles are the *most economical* method of installing tunnels in stable soils and on mild slopes. For more complete information write for an opinion by our experienced technical staff.

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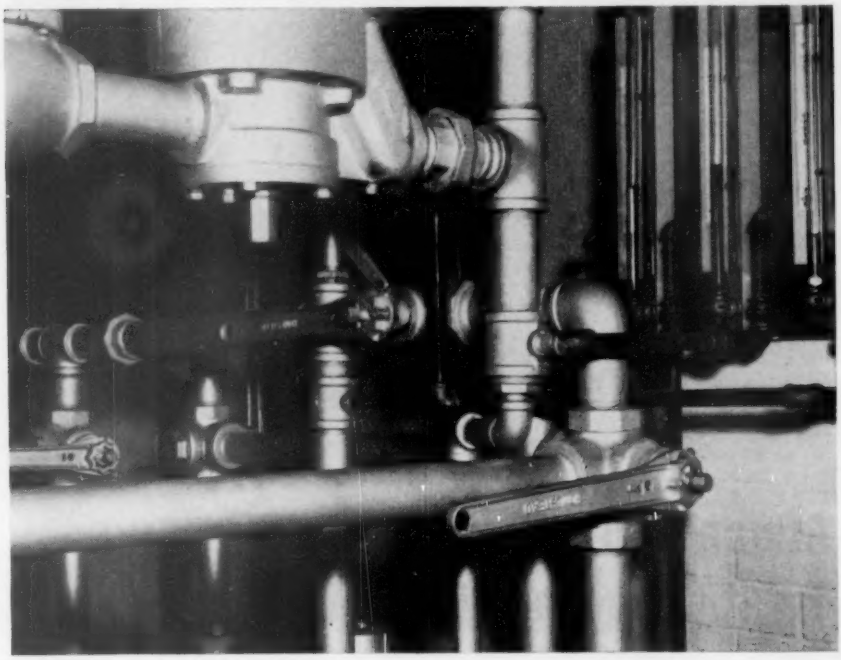
CONCRETE PRODUCTS DIVISION
GENERAL OFFICES:
AMERICAN-MARIETTA BUILDING
101 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS, PHONE: WHITEHALL 4-5600

CLOSE TOLERANCE—KEYNOTE TO LOW-COST MAINTENANCE—is yours with Homestead® Lubricated Plug Valves. Vital to efficient fluid control, this close tolerance between sealing surfaces (.002″ maximum clearance on sizes up to 2″, .003″



to .005″ maximum on larger sizes) plus Homestead's high pressure lubricant system guarantee complete coverage of sealing surfaces. You are assured added protection against corrosive, abrasive, or erosive line fluids as well as a longer lasting seal against leakage. Sticking is eliminated, too, by downward movement of plug during each lubrication. The net result for you is positive fluid control at very low cost per year.

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"Serving since 1892"
P.O. Box 48, Coraopolis, Pennsylvania

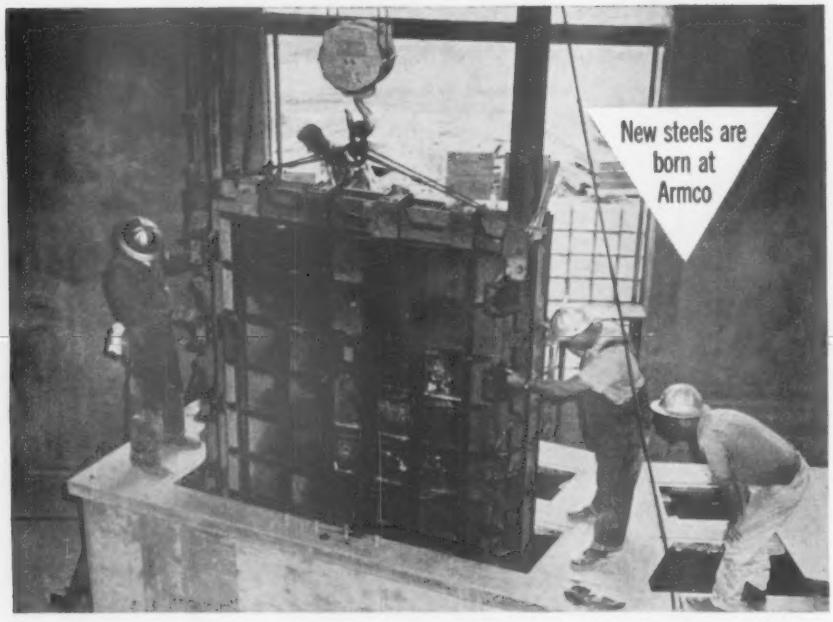
48
Please send Reference Book 39-1 and prices on Homestead Lubricated Plug Valves:

Name.....Title.....

Company.....

Address.....

City.....Zone....State.....



Armco Sluice Gates Help Boost Treatment Plant Capacity

The gate being lowered into position above is one of three 72-inch by 96-inch Armco Sluice Gates installed at the Hyperion Sewage Treatment Plant near El Segundo, California. These gates, located in the headworks building and equipped with electrically operated lifts, are one phase of a plan to increase plant capacity. The gates, normally open, are closed only for maintenance work.

Two smaller Armco Sluice Gates and two stainless steel flap gates were used in other parts of the plant.

Armco can help solve *your* gate problems, too. For complete data, write: Armco Drainage & Metal Products, Inc., 4950 Curtis Street, Middletown, Ohio.

ARMCO DRAINAGE & METAL PRODUCTS

ARMCO®

Subsidiary of ARMCO STEEL CORPORATION

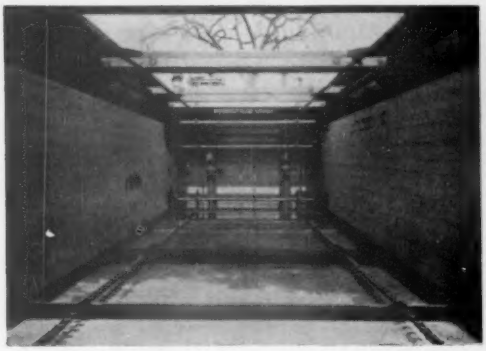
OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation

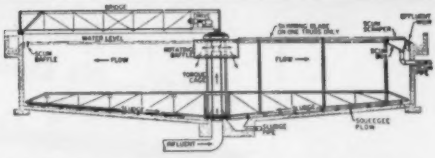
WHICH SLUDGE COLLECTOR

can do the best job for you?

For maximum efficiency . . .
minimum disturbance of flow . . .
choose LINK-BELT
STRAIGHTLINE sludge collectors

For large installations
where construction economies
are vital . . . it's LINK-BELT
CIRCULINE sludge collectors





STRAIGHTLINE COLLECTORS are scraper conveyors made in various styles to handle sludge and scum in *rectangular tanks*. Straightline design means the shortest possible travel for the collected material. It also permits a steady slow speed of the collecting flights that is uniform over the entire floor surface of the tank. This results in maximum efficiency with minimum disturbance to the flow. Straightline collectors can also be installed in the Link-Belt Uniflow settling tank—an improved rectangular design combining a rapidly sloping bottom with a system of multiple effluent weirs.

CIRCULINE COLLECTORS are installed in either rectangular or round tanks. Link-Belt offers four series—R, S, T and C. Series R are usually installed in circular tanks and are used to remove settled sludge from the tank floor and scum from surface of liquid. Series S are for square tanks, or rectangular tanks where sludge is collected only from the influent end of tank. Series T are similar to Series R, except they are built to withstand torques encountered in removing heavy settled solids. Series C have both the economical feature of circular tank construction and the positive sludge and scum collection of a straightline sludge collector.

Sludge collectors are only a part of the broad line of Link-Belt sanitary engineering equipment. Get in touch with the Link-Belt office nearest you. Our sanitary engineers will be glad to work with your engineers, chemists and consultants . . . help you get the finest in modern treatment methods. Or write for Water, Sewage and Industrial Waste Treatment Equipment Book 2617 and Uniflow Settling Tank Folder 2648.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

15,000

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Sanitary Engineering Regional Offices—Colmar, Pa., Chicago 9, Kansas City 8, Mo., San Francisco 24. Sales Offices in All Principal Cities. Export Office, New York 7. Representatives Throughout the World.

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Beautiful Glazed Tile for Complete Corrosion Resistance

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Comparable in Cost to Concrete or Steel... No Continuing Maintenance

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Installations can be made under a contract which covers everything from the original design, based on full knowledge of the chemical, physical and mechanical requirements, to the finished job ready for use.

Write for complete information

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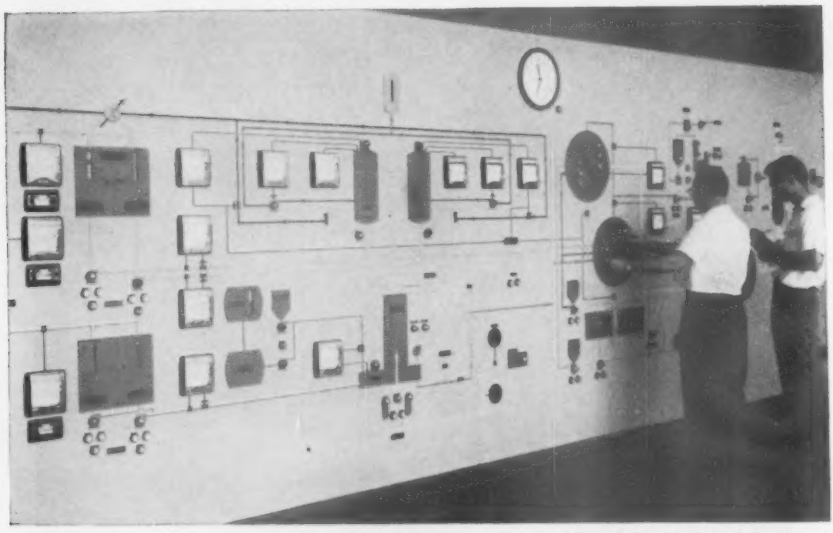

Central Graphic Control Panel for Boeing's Industrial Waste Treatment Plant. Panel includes controllers for flow and liquid level of various tanks, as well as recorder-controllers for the Foxboro ORP meters. Consulting Engineers: Wilson & Company, Salina, Kansas.

Foxboro continuous control system

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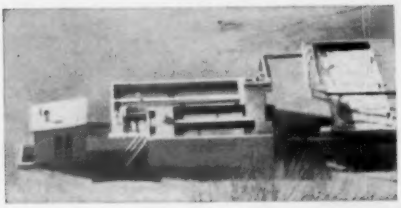

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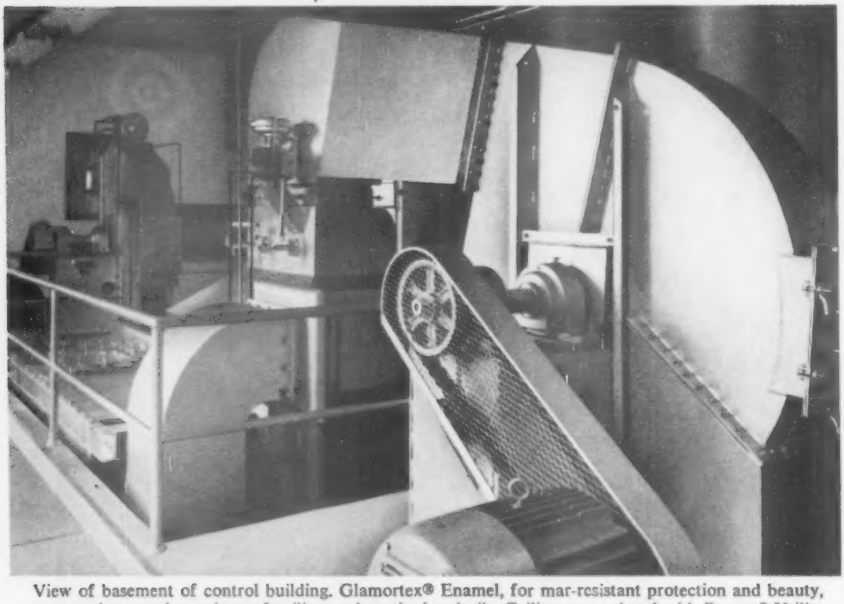

View of basement of control building. Glamortex® Enamel, for mar-resistant protection and beauty, was used on steel members of ceiling and on the handrails. Ceiling was painted with Ramuc® Utility Enamel, ideal for surfaces exposed to severe condensation, fumes, splashing. Incinerator equipment was painted with Inertol High-Heat Aluminum Paint No. 445, a high quality silicone-base coating.

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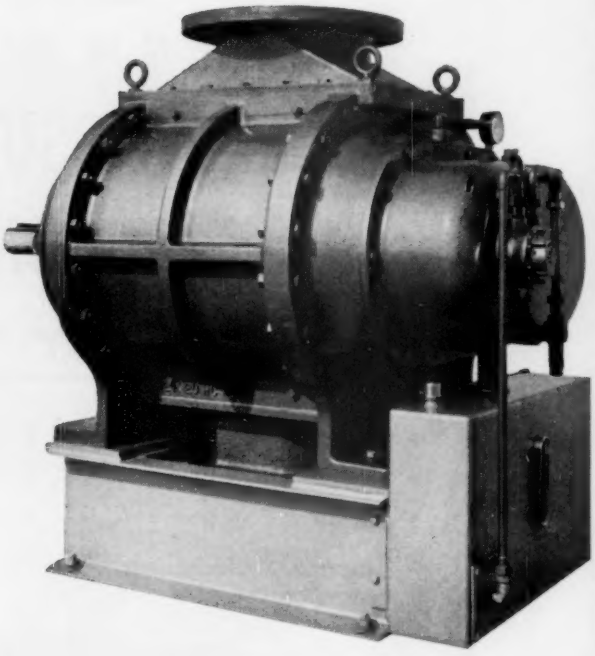

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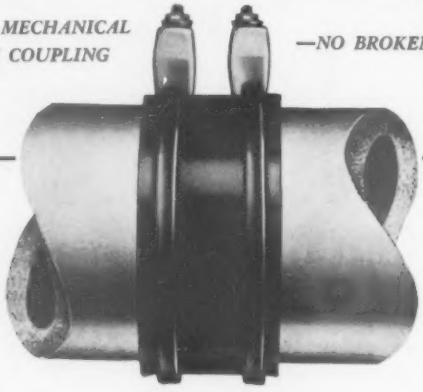

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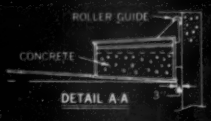

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By exclusive arrangement with General American Transportation Corporation, INFILCO offers the "MONODECK" floating cover for sludge digesters in a full range of sizes. This cover, designed by Wiggins, offers the same basic structural features which have been incorporated in the 214 foot diameter gas holder for the City of Long Beach, California. The essential features and advantages of the "MONODECK" type cover are:

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4. Up to 60 feet in diameter, the "MONODECK" cover can be assembled complete outside the tank and lifted by the contractor's crane into position. Tank and cover can, therefore, be constructed simultaneously. Savings in erection costs may be as much as 50% on the larger covers.
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A discussion of the economics of variable speed pumps for sewage works

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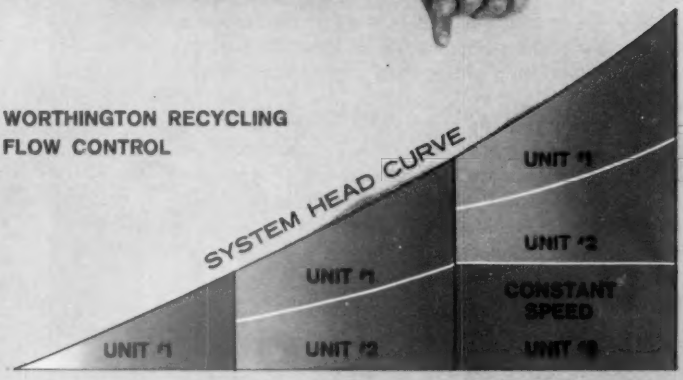
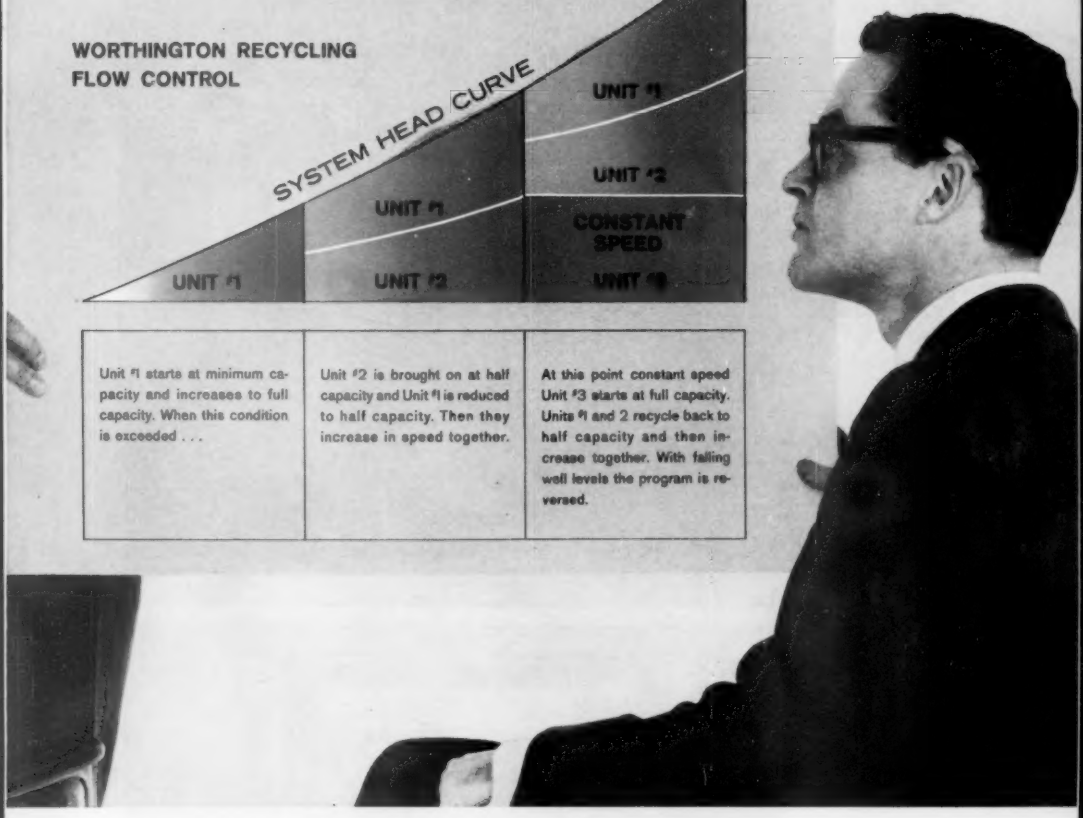
The system that takes maximum advantage of the possibilities of variable speed operation is Worthington's Recycling Flow Control. Operated by a Worthington engineered control, the system maintains pre-

SEWAGE WORKS REPORT
from Worthington



Unit #1 starts at minimum capacity and increases to full capacity. When this condition is exceeded . . .	Unit #2 is brought on at half capacity and Unit #1 is reduced to half capacity. Then they increase in speed together.	At this point constant speed Unit #3 starts at full capacity. Units #1 and 2 recycle back to half capacity and then increase together. With falling well levels the program is reversed.



cise operation of variable speed pumps.

The float control will handle any number of variable speed and constant speed pumps. How it works in a plant with two variable speed and one constant speed pump is shown above.

The Recycling Flow Control is the latest development of Worthington's continuous work in the public works field. It's another reason that to get the best and the latest you should come to Worthington first. Major public works products include: pumps, comminutors, compressors, engines, and turbines.

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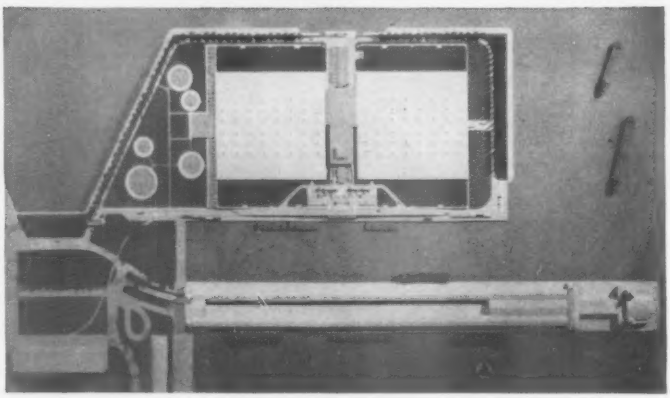
64 JEFFREY Chemical Mixing units at Chicago's new Central District Filtration Plant

Sixteen chemical mixing basins, equipped with 64 Jeffrey mixing units, will serve the "world's largest municipal water filtration plant" when it goes into operation in 1962. Each basin has a rated capacity of 60 million gallons per day, giving this plant a daily capacity of 960 mg.

Jeffrey equipment has seen years of service in other Chicago water and sewage treatment plants. It has proved its worth and dependability here, as well as in hundreds of other plants throughout the country – small plants as well as large.

Jeffrey's Sanitary Engineers offer help on problems involving plant layout and equipment. Bulletin 952 describes these services. The Jeffrey Manufacturing Company, 902 North Fourth Street, Columbus 16, Ohio.

Air view of the Central District Filtration Plant under construction.



A model showing what the plant will look like when completed.

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Developed by Fisher engineers and Dr. William D. Hatfield, "dean" of American Sanitation Chemists, the unit has many built-in, speed-inducing features. Included are a glassware rinser, *dual* water fixture (for distillation and water vacuum work simultaneously at the same cup-sink), automatic 2-ml pipets and reagent block. Easy to install, the "packaged lab" provides for analysis of incoming sewage, digestor products, sludge and effluent. Four models (each complete with furniture, instruments, apparatus and chemicals) to handle nearly every plant requirement—from the small town (population under 7,500) to cities (over 25,000).

The "heart" of the Fisher-Hatfield system is a 5-ft-wide Fisher Unitized sink and a 4-ft-wide, 3-drawer lab bench. Drawers are subdivided into compartments to enable new personnel to learn the various tests quickly, since equipment for each test is supplied in the proper quantity, quality and grouping—*at the operator's fingertips.*

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. . . in the 16-page booklet on the Fisher-Hatfield Sewage Testing Unit, 135 Fisher Building—Pittsburgh 19, Pa. B-115 b

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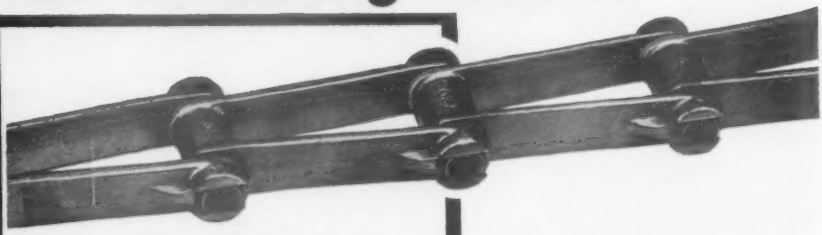
Webster CHAIN for Handling Wastes



No. 720-S CHAIN

Designed especially for straight-line sludge and grit collectors, where long economical service is important. Pin and cotter construction. Pins have "T" heads securely fitted between lugs cast on side bars. This design prevents the pins from turning in the side bars, thereby distributing the wear over a large area in the barrels of the links. Available in malleable iron or Duramal which is approximately 20% stronger than malleable iron.

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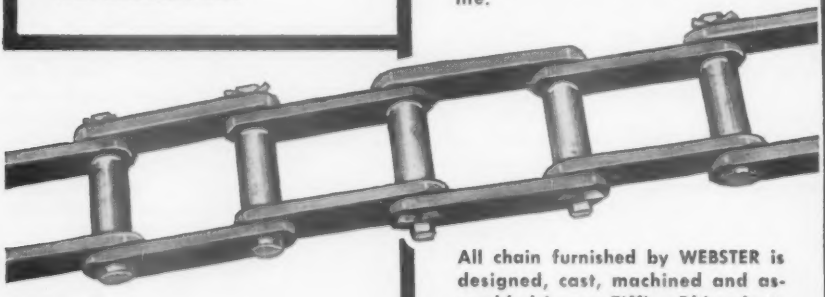
Designed for handling abrasive materials such as encountered in grit collectors. The barrels of the links are eliptical in shape to provide more material at point of greatest wear. This feature, together with the close-fitting joints, steel coupler links, and stationary steel pins provide maximum performance, sustained accuracy of pitch, and exceptionally long life.



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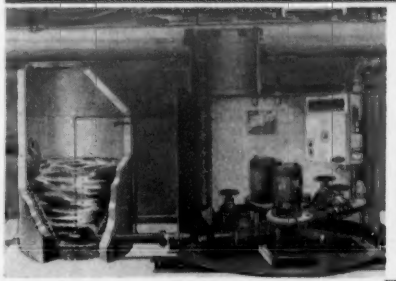

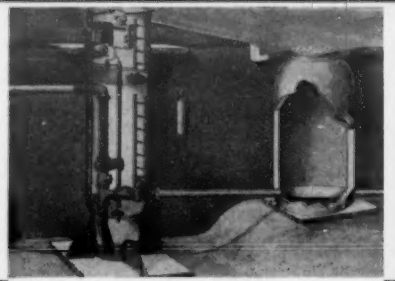

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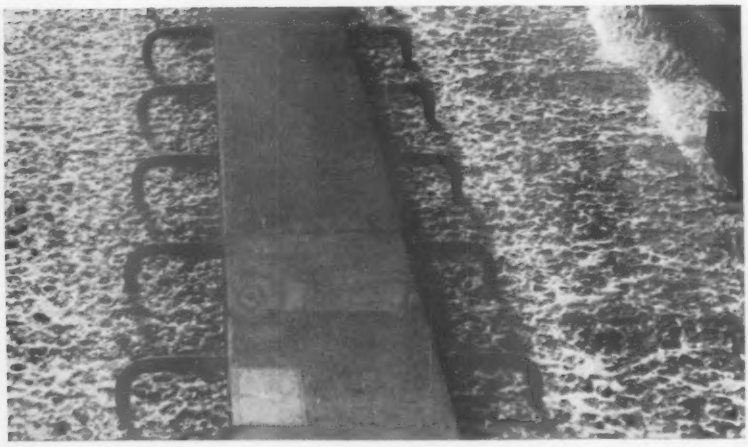

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The D-O INKA system is an exclusive development, based on a new principle of operation. It not only offers higher oxygenation capacities but also high circulating velocities that promote optimum mixing conditions. Simple, low pressure fans are used rather than conventional blowers. No air filters are required. Oxygen transfer rates from 10 ppm to 150 ppm per hour and higher are feasible. Power costs range from 0.20 Kwh to 0.45 Kwh per pound of oxygen dissolved, depending on transfer rates. Construction and maintenance costs are low. For full details, write for Bulletin No. 7317 to Dorr-Oliver Incorporated, Stamford, Connecticut.

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Sewage Works

WASTE STABILIZATION LAGOONS—DESIGN, CONSTRUCTION, AND OPERATION PRACTICES AMONG MISSOURI BASIN STATES

By Willis Van Heuvelen, Jack K. Smith, and Glen J. Hopkins

Respectively, Executive Officer, North Dakota State Department of Health, Bismarck, N. Dak.; Executive Secretary, Missouri Water Pollution Board, Jefferson City, Mo.; and Regional Engineer, U. S. Public Health Service, Kansas City, Mo.

This paper is a report of the Subcommittee of the Missouri Basin Engineering Health Council. It was approved and released for publication in September 1959 by the following members of the Council: William N. Gahr, Director, Division of Sanitation, Colorado State Department of Public Health; Paul J. Houser, Director, Division of Public Health Engineering, Iowa State Department of Health; Dwight Metzler, Director, Division of Sanitation, Kansas State Board of Health; Frank L. Woodward, Director, Division of Environmental Sanitation, Minnesota State Department of Health; Albert W. Happy, Jr., Director, Section of Environmental Health, Missouri Division of Health; C. W. Brinck, Director, Division of Environmental Sanitation, Montana State Board of Health; T. A. Filipi, Director, Division of Sanitation, Nebraska State Department of Health; Willis Van Heuvelen, Chief of Environmental Sanitation Services, North Dakota State Department of Health; Charles E. Carl, Director, Division of Sanitary Engineering, South Dakota State Department of Health; and Arthur E. Williamson, Director, Division of Environmental Sanitation, Wyoming State Department of Public Health.

Waste stabilization lagoons for treating raw sewage have become popular in recent years, particularly among smaller municipalities where low construction and operating costs usually offer a significant financial advantage over other recognized treatment methods. Communities in the Missouri Basin now using stabilization ponds as the sole mode of treatment number more than 300. North Dakota and Missouri each have approximately 100 installations. In the Southwest, and elsewhere to a limited extent, basically similar "oxidation ponds" commonly are used for secondary or additional treatment. Oxidation ponds number more than 250 in the Southwest.

At its 1956 meeting at Helena, Mont., the Missouri Basin states adopted the term "waste stabilization lagoons." Similar action was taken by the Great Lakes–Upper Mississippi River Board of State Sanitary Engineers at the March 1959 meeting at Chicago, Ill. In this report, the terms "waste stabilization lagoons," "stabilization lagoons," and "lagoons" are used interchangeably. The term "ponds"

is still used by some of the Basin states.

Basically, the stabilization process consists largely of the interactions of bacteria and algae. Bacteria digest and oxidize the constituents of sewage and render it innocuous. Algae utilize carbon dioxide, ammonia, and other substances resulting from bacterial action and through photosynthesis produce oxygen needed to sustain the treatment process. During the detention period, the objectionable characteristics of sewage largely disappear.

Until about 1952, the use of lagoons as sole and permanent sewage treatment facilities generally was regarded as poor engineering practice. Now, the great upsurge of interest in their use at many localities throughout the country emphasizes the desirability of documenting the design, construction, and operating practices commonly used. At its 1958 meeting at Deadwood, S. Dak., the Missouri Basin Engineering Health Council appointed a committee to accomplish this objective.

The committee soon realized that waste stabilization lagoons have been adapted for successful use under highly varying conditions. As with other methods, they can be designed to provide intermediate, secondary, or higher levels of treatment. Variations in water quality, rainfall, evaporation, water consumption, soil conditions, nature and use of receiving watercourses, dilution water available, and other factors permit design to vary widely. For example, to maintain a satisfactory water level, North Dakota accepts heavier loadings in the western part of the state than are recommended for the eastern part, where rainfall, evaporation, and other factors differ considerably.

The many instances of satisfactory performances in installations of varying design so impressed the committee that it concluded that the development of rigid design criteria is unwarranted. Its members elected to outline ranges of design practices satisfactorily employed in the Basin, leaving each state wide latitude as to specific practices to be recommended.

The material contained in this report is based on the best information now available, and is heavily influenced by experience in states having a large number of installations. It is anticipated that it will be subject to review and revision as additional information becomes available. The report outlines experiences and practices that may be useful to those interested in this method of disposal. The committee recognizes that complete uniformity among the several states is neither indicated nor desirable.

The text is developed on the premise that a stabilization lagoon is a proved method of waste disposal which should receive the same consideration as other methods of treatment when engineering and economic analyses are being made.

The terms "recommended" and "should" as used in this report are used to denote widely used practices, and are not intended to imply a mandatory requirement for any specific state or installation.

Preliminary Engineering Report

A preliminary engineering report on the proposed facility should be prepared and submitted to the appropriate state agency for review prior to development of final plans and specifications. This report should indicate the location and topography of the proposed site, volume and characteristics of sewage and industrial wastes, size and shape of units, surface and subsurface soil conditions, nature of receiving watercourses, downstream water uses, dilution water available, and geographical location with respect to residences, commercial development, water supplies, and other topographic features. As certain installations receiving wastes abnormally high in sulfates (above 750 mg/l) have presented

some problem of odor, the preliminary report may well include the sulfate concentration in the water supply. Where the sulfate content is above 1,000 mg/l, the community should be prepared to add sodium nitrate during critical periods to minimize odors.

Preliminary reports should be reviewed and evaluated on an individual basis.

Location

Stabilization lagoons, like other sewage treatment facilities, should be located as far away from existing and future residential and commercial developments as is reasonably practicable and economically feasible. Consideration should be given to the probable course of possible expansion and the direction of prevailing winds. Other factors permitting, preference should be given sites that permit unobstructed wind action on the water surface.

Early installations had the benefit of considerable separation from residences, and the impression developed that substantially greater remoteness is required for lagoons than for other sewage treatment devices. Experience has demonstrated that a lagoon usually can be located as close to habitation and other developments as any other sewage treatment process. Generally, it is recommended that isolation requirements for lagoons be identical with and determined by the same factors that are associated with other sewage treatment plants.

While no evidence of underground pollution affecting water supplies has been attributed to existing installations, the significance of pollution of underground waters is so great that this aspect of location merits very serious consideration. Except for fissured rock or coarse gravel formations, significant horizontal travel of bacteria through soil is not probable. But chemical pollution, including detergents, may travel much farther in normal soil formations.

Area and Loading

Early stabilization lagoons in North Dakota were located in areas of inexpensive, relatively level land and were basically designed for one acre of water surface per 100 population or population equivalents expressed in terms of 5-day BOD. This basis of design was predominantly one of economics and experience, since cost was well within the financial capabilities of North Dakota communities and the installations performed satisfactorily. Later experience in North Dakota revealed that substantially heavier loadings, arranged primarily to insure water level maintenance, could be handled successfully. Similar experiences have been observed in Missouri, Kansas, Nebraska, and Wyoming.

The 5-day BOD still is used as one factor of design in most states of the Missouri Basin. Total first-stage BOD has been used on occasion, particularly where significant industrial wastes are involved.

It is now well accepted that loadings and, consequently, the lagoon area are influenced by many factors, including, but not necessarily limited to: water consumption, evaporation, rainfall, seepage, the degree of treatment desired, growth prospects, and the basic plan of operating the facility. Optimum loading and area should reflect appropriate consideration to all pertinent factors.

In cold climates, where substantial ice cover may be expected for an extended period, it may be desirable to operate the facility to retain all wintertime flows. In other climates, lagoons may be operated on a flow-through principle. In some instances, essentially complete retention may serve as a basis of design rather than BOD loadings.

Flow-through lagoons receiving raw sewage normally employ a minimum of 60 days' retention, with 90 to 120 days frequently specified. A high de-

gree of coliform removal is assured even with a 30-day retention. Installations receiving partially treated sewage may provide less retention, usually in relation to the removals accomplished by prior treatment.

BOD loadings of from 0.23 to 0.78 lb/day/1,000 sq ft (10 to 34 lb/day/acre) are used successfully throughout wide areas of the Missouri Basin. The lower range permits longer retention and greater flexibility for handling future increases in waste loadings from population or industrial growth. On the other hand, the lower loading generally results in a smaller volume of sewage per unit of area and enhances the possibility of operational difficulties brought on by the inability to maintain satisfactory liquid depth, particularly in areas of low per capita water use, low rainfall, high evaporation, or significant seepage. While primary consideration is given to organic loading, the area finally decided on is based frequently on both the organic and hydraulic loading. For some types of industrial wastes, other criteria may be considered foremost.

Lagoons have clearly demonstrated their ability to handle substantially higher loading during summer periods, making them particularly appropriate for resort areas where heavy summer populations are normal.

BOD loadings up to 1.56 lb/day/1,000 sq ft (68 lb/day/acre) have been employed successfully in Missouri, particularly in subdivisions where land costs are high and the lagoon is planned as an interim installation to be replaced in reasonable time by trunk sewers leading to a more permanent installation.

For lagoon units operated in series, the designer should recognize that the entire organic load will be applied to the primary unit. Where lagoons are used to provide additional treatment for the effluent of conventional plants, the area should reflect the reduction in BOD accomplished through prior treatment. When a low algal content in the effluent is desired, the units may be operated advantageously in parallel during the fall, winter, and early spring when algae development is less intensive, and in series during the summer months.

Lagoons should be of such shape that there are no narrow or elongated portions. Rectangular units with the length not exceeding three times the width and round or square shapes are considered most desirable. Dikes should be rounded at corners to minimize accumulation of floating material.

Multiple-Unit Installations

Many Missouri Basin installations employ multiple units, some operating in parallel, others in series. Series operation is beneficial where a high level of BOD or coliform removal is important. The effluent from secondary units in series operation has a much lower algal concentration, with a resultant decrease in color and turbidity. Many serially-operated multiple-unit installations have been designed to provide virtually complete retention of wastes.

Many installations can be operated either in series or parallel. Except for small installations, this flexibility has considerable advantage, particularly where loading is light or a community is installing a new sewer system. In the latter case, the entire discharge can be put into a single unit until such time as a substantial number of connections can be made, thereby facilitating the maintenance of a satisfactory water level. This also may be important in areas of low water usage, high evaporation, or considerable seepage. As the sewage load increases, or as other conditions warrant, the units may be operated either in parallel or series. For small installations (six to eight acres) a single unit seems conducive to better circulation, but reasons other than circulation make two

units preferable even for small installations.

Another method employed to alleviate the initial-filling problem is to construct a depression about one foot deep in the inlet, gradually tapered to the normal bottom elevation.

The additional cost of equipping units for both series and parallel operation is usually nominal. In some instances, actual savings can be demonstrated because of the lesser volume of earth moving needed to adopt two or more smaller units to the topography. Except for small installations (less than six or eight acres) it is recommended that units be designed to permit both series and parallel operation.

Surface Runoff

Lagoons should not receive significant amounts of surface runoff. If necessary, provision should be made for diverting surface water around the ponds. For new installations and for installations where maintenance of a satisfactory water depth may be a problem, the diversion structure may be designed to admit surface water to the lagoon when necessary. Silt that would be carried into the installation with surface runoff must be considered.

Dikes

Dikes should be constructed in a way which minimizes seepage. Compaction afforded by the use of conventional construction equipment is usually adequate. Vegetation should be removed and the area upon which the embankment is to be placed should be scarified. It is generally unnecessary to key the dikes into impervious subsoil, but this precaution may be advisable for sandy top soils.

The dikes should be wide enough to accommodate mowing machines and other maintenance equipment. Eight feet is generally considered adequate, and narrower dikes may be approved for small installations.

Slopes may be influenced by the nature of the soil and the size of the installation. For outer slopes, a vertical-to-horizontal ratio of 1:3 is satisfactory, although economical use of excavated material may warrant flatter slopes. Inner slopes are generally designed from 1 vertical to 3 to 4 horizontal, although slopes exceeding 1 on 5 are sometimes specified for larger installations, and slopes steeper than 1 on 3 may be warranted for small installations. Flat inner slopes have the disadvantage of adding shallow areas conducive to emergent vegetation. Wave action is more severe for larger installations, warranting consideration of flatter inner slopes. Observation reveals that a given installation will develop a particular slope at the water line rather independent of the slope originally provided, the constructed slope being adjusted by wave action to give a "dished" effect near the water line.

The freeboard is to some extent influenced by the size and shape of the installation, as wave heights are greater on larger bodies of water. Freeboard should be sufficient to facilitate necessary maintenance operations without accident hazard. Three feet above maximum liquid level is usually specified as minimum freeboard. But two feet is considered adequate by some states, particularly for installations of 6 acres or less not exposed to severe winds.

Liquid Depth

Optimum liquid depth for adequate circulation is influenced to some extent by lagoon area, greater depths being allowed for larger units. The basic plan of operation may also influence depth. Shallow lagoons encourage the growth of emergent vegetation and consequently mosquito breeding. Experience in the Kansas City area has demonstrated the efficacy of depths of two to three feet during periods of prolonged cool, cloudy weather oc-

casionally encountered in early spring or late fall. These installations serve subdivisions, are heavily loaded, and are less than 10 acres in area. It also has been demonstrated that greater depths are desirable in summer to discourage emergent vegetation.

There is a distinct advantage for facilities which permit operation at selected depths up to five feet, and provision for additional depth may be desirable for large installations. Facilities for adjusting pond levels can be provided at small cost.

Where winter retention is visualized, the operating level can be lowered as desired before ice formation and gradually increased by the retention of winter sewage flow. In the spring, the level can then be lowered to any desired depth at the time surface runoff and dilution water are generally at a maximum. Shallow operation can be maintained during the spring, increasing the depth as necessary to discourage emergent vegetation. In early fall, the levels can be lowered before cloudy periods are encountered and again be ready for retention of winter sewage. In areas of high evaporation, as in western Kansas, a full lagoon in late spring may be an operating objective.

Devices which permit operation at various depths are desirable for any installation; however, it is not considered that these facilities should be made mandatory for small installations. For lagoons 30 acres or larger, provision for periodic operation at depths greater than five feet may be advantageous.

Lagoon Bottom

The lagoon bottom should be made as level as possible with conventional dirt-moving equipment and operations. Except around the inlet, as discussed elsewhere, the finished elevation should not vary more than six inches from the average elevation of the bottom.

The lagoon area should be cleared of excessive vegetation and debris. This material should not be included in the waterside two-thirds of the embankment, but it may be used judiciously in the outer third. Rock or other porous material may also be placed in the outer one-third of the embankment, but should be covered with earth to facilitate maintenance.

The bottom should be well compacted and relatively tight to avoid excessive seepage. Removal of porous top soil and compaction of subsoil improve the water-holding characteristics of the bottom, and adequate compaction may be as important in this regard as soil characteristics. Proper compaction usually can be accomplished by use of conventional earth-moving equipment, although additional treatment such as sheep's-foot rolling may be justified.

The ability to maintain a satisfactory water level in the lagoon is one of the most important aspects of design; one for which the consulting engineer must be primarily responsible. Where excessive percolation is a problem, increased hydraulic loading or partial sealing may merit consideration. Porous areas such as gravel pockets should receive particular attention. Removal of gravel or sandy pockets and replacement with well-compacted clay or other suitable material may be indicated. Limiting values of acceptable percolation may be merited in some areas as a measure against which sealing of porous bottoms will be required.

Information is meager on lagoon sealing in areas where high seepage rates are expected. Some clogging of permeable soil appears to result from sewage solids, even though the sludge layer is extremely thin. Some lagoons have been built with multiple units to facilitate heavy original loadings. The entire sewage load is discharged to the smaller area, and when water-holding capabilities are obtained, the flow is diverted to another unit. Some

use has been made of bentonite, asphaltic coating, clay, and other sealing materials.

Influent Lines

The influent line to primary units should discharge far enough from any bank to insure minimum interference with normal circulation. For small installations, the discharge should be near the center of the lagoon. For medium-sized installations, there appears to be little advantage in locating the inlet more than 200 feet from the nearest bank, with 400 feet desirable for lagoons larger than 40 acres. Multiple inlets appear to have some advantage in dispersing solids uniformly throughout the lagoon, particularly in large installations.

Gravity inlets to primary units should slope on a uniform grade from the manhole at the terminus of the outfall sewer to a point approximately one pipe diameter below the toe of the inner or waterside slope of the dike. From this point the pipe is usually laid on a zero grade to the point of discharge, with the top of the pipe being slightly below the average elevation of the lagoon floor. The manhole at the terminus of the outfall line should be located as close to the dike as topography permits, and its invert should be at least six inches above the normal operating water level to provide sufficient hydraulic head without surcharging the manhole. Placing the bottom of the pipe on the lagoon floor, or supporting it in a submerged dike or on piling or other pipe supports, or the use of shallow dike-formed areas around the inlet are not recommended; there is some evidence that these construction features may interfere with normal circulation.

Gravity lines and inverted siphons have been used successfully in many installations to discharge untreated sewage to primary units. No stoppages or other operating problems have been experienced. Submerged portions of the influent line are under slight pressure; thus, appropriate materials and methods of construction should be used. The size of the line should not be reduced along the submerged portion. Pipe materials in general underground use may be satisfactory for gravity influent lines. Attention should be given to the possibility of septicity, soft foundations, ice cover, and other loading problems.

A horizontal influent line may discharge advantageously into a shallow, saucer-shaped depression. This depression should have a minimum depth equivalent to the outer diameter of the pipe and a maximum depth of the pipe diameter plus one foot, with a radius varying from 25 to 100 feet depending on the size of the unit. The depression, intended to facilitate submergence of sewage solids while the lagoon is filling, is particularly important for installations serving new collection systems.

Where it is necessary to pump sewage into the lagoon, the pressure main within the cell should be laid in the same way gravity lines are laid. High points in the force main should be avoided to prevent the creation of air pockets, and a gate valve should be installed at a location which will permit repairs without draining the lagoon. Maintenance and ice problems should be considered in valve location. If there is a possibility of siphoning the contents of the lagoon back through the pumping station, preventive steps should be taken.

Influent pipes discharging vertically are successful, but offer no apparent advantage. Some states discourage a vertical discharge because of possible accumulation of grit in the line. For horizontal discharge, a suitable concrete splash plate should be constructed around the point of discharge to minimize erosion.

Overflow Structures

Overflow structures should be designed to permit operation of the la-

goon at selected water depths, although this should not be considered mandatory. The outlet structure should permit lowering the water level at a rate of not less than one foot per week while the facility is receiving its normal load. It should be large enough to permit easy access and normal maintenance operation. Provision for complete draining of the lagoon is desirable.

During ice-free periods, discharge should be taken just below the water surface. This releases effluent of the highest quality and insures retention of floating solids. For operation during periods of ice cover and ice formation, the discharge is usually from a point substantially below the surface, but some states have used surface overflow pipes during prolonged freezing. Overflow structures generally comparable to a sewer manhole are most frequently employed, with selected-level discharge facilitated through valved piping or other adjustable overflow devices. Stop planks of creosoted lumber have been used in some cases. Overflow lines should be vented if the design would otherwise permit siphoning.

For flow-through lagoons, the maximum rate of effluent discharge is considerably less than the rate of peak sewage flow because of lagoon losses and the leveling of peak flows.

Interconnecting Piping

Interconnecting piping for multiple-unit installations should facilitate maximum liquid retention in the facility. In some states, cast iron is specified for interconnecting piping. Valving or other arrangements to regulate flow between structures are recommended. Flexible depth control in each unit of a multiple-unit installation is desirable. The influent pipe to the secondary unit should discharge horizontally at or near the lagoon bottom to minimize the need for erosion control, but it can be located as near the dike as construction permits. If parallel operation is to be provided, the inlet design should be the same as that used for a primary unit.

Industrial Wastes

Lagoons may be used for treating industrial wastes that are amenable to biological treatment or for a mixture of organic industrial wastes and domestic sewage. Installations now are serving oil refineries, slaughter houses, dairies and creameries, poultry processing plants, and rendering plants. Special study should be given to industrial wastes whenever they constitute a significant portion of the total load. Recommendations for loading and area already discussed may be used as a guide. Toxic materials in concentrations which would interfere with other biological sewage treatment processes should be handled in lagoons only after thorough study and evaluation.

Miscellaneous

Embankments should be seeded from the outside toe to the water line to minimize erosion and facilitate weed control. Alfalfa and similar long-rooted crops should not be used. The county agricultural extension agent usually can recommend a hardy, local grass which will not interfere with the water-holding capacity of the dike.

Riprap or other protection is warranted only under unusual conditions, such as protection of dikes from erosion due to severe flooding of the adjacent watercourse, or extremely severe wave action. The possibility of floods should not be overlooked.

Lagoons should be fenced to exclude unauthorized personnel and livestock. Fences consisting of three or four strands of tightly stretched barbed wire are completely satisfactory unless swine or poultry have access to the area. Barbed-wire fences do not collect as much wind-blown material as woven-wire fences. For lagoons serv-

ing schools, resorts, or similar facilities, chain-link or other special fencing may merit consideration. At least one vehicle-access gate should be provided.

The nature of the facility should be clearly designated through appropriate signs located at suitable intervals along the fence. The signs should state that the facility is a sewage treatment device and warn against trespassing.

For lagoons serving combined sewer systems, suitable grit removal facilities may be appropriate. Excess grit may interfere with initial discharge and circulation.

Study and evaluation of lagoons may be greatly expedited by providing a flow-measuring device for both influent and effluent. These devices need not provide continuous measurement, and may be quite inexpensive. For example, manholes on both influent and effluent sewers may be constructed to hold a weir plate which can be slipped into place during periods of flow measurement. A uniform receptacle for the weir plate will permit the state agency to use a standard weir plate to expedite special studies.

Provision for recirculation has been included in some installations, but no advantage has been demonstrated or is any visualized within the range of loadings covered in this report.

Soil sterilization along the shallow water portion of the dikes has been found effective in controlling weeds in Kansas. The sterilizer should resist leaching and be toxic to weeds, but not algae. It can be applied by power spraying prior to filling of the lagoon.

MEETINGS OF INTEREST

Sept. 15–16	**36th Annual Meeting, Illinois Association of Sanitary Districts,** Rockford, Ill. R. E. Anderson, Secretary, North Shore Sanitary District, Dahringer Road, Waukegan, Ill.
Sept. 20–23	**United States Civil Defense Council,** Leamington Hotel, Minneapolis, Minn. Elliott R. Jackson, Municipal Auditorium, Atlanta, Ga.
Oct. 2–9	**Inter-American Association of Sanitary Engineering,** Hotel Carrasco, Montevideo, Uruguay. F. W. Montanari, 414 Walnut St., Room 302, Cincinnati 2, Ohio.
Oct. 10–14	**American Society of Civil Engineers,** Statler Hotel, Boston, Mass. W. H. Wisely, ASCE, 33 West 39th St., New York 18.
Oct. 18–21	**First Effluent and Water Treatment Convention,** The Seymour Hall, London, W. 1, England. Thunderbird Enterprises Ltd., 140 Cromwell Rd., London, S. W. 7.
Oct. 31–Nov. 4	**American Public Health Association,** San Francisco, Calif. Berwyn F. Mattison, M.D., Executive Director, 1790 Broadway, New York 19.
Nov. 28–30	**Conference on Water Quality in the Columbia River Basin,** Washington State University, Pullman, Wash. W. H. Knight, Technical Extension Services, Washington State University, Pullman.
Dec. 12–14	**National Conference on Problems and Progress in Water Pollution Control,** Sheraton-Park Hotel, Washington, D. C. U. S. Public Health Service, Washington, D. C.

WET OXIDATION OF SEWAGE SLUDGE*

By E. Hurwitz and Wm. A. Dundas

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The Metropolitan Sanitary District of Greater Chicago, faced with the problem of disposing of 200 tons of sludge more than the capacity of its present facilities, became interested in wet air oxidation as a method of sludge disposal. The Sanitary District was created by the State of Illinois in 1890 for the specific purpose of protecting the water supply of the City of Chicago and communities contiguous to it. It has grown in area from 185 square miles in 1890 to 922 square miles in 1959. It now serves a population, including Chicago and 106 adjoining municipalities, of some 4.8 million human population and an additional industrial population equivalent to 3.872 million. In 1958 the average daily sewage flow of the area was 1,103 mgd. The solids recovered at the three major plants averaged 811 dry tons per day, excluding grit. Of this quantity of sludge an average of 436 tons of activated sludge were heat-dried for disposal as a low grade fertilizer; 163 tons were air dried and stock-piled in a sludge disposal area; and 212 tons were pumped to sludge lagoons.

Since lagooning raw sludge, even as a temporary expedient, has not been a suitable method of disposal, The Metropolitan Sanitary District of Greater Chicago began a search for a satisfactory replacement method. The method selected was wet air oxidation.

The Wet Air Oxidation Process

The wet air oxidation process is a method of incineration which uses the principle of wet combustion to degrade the organic matter in sludges. Basically, the process is chemical oxidation, under pressure, and at elevated temperatures, of combustible material in water or suspension. Atmospheric oxygen is the oxidant and the organic matter of sewage sludge, or any other organic substance, is the combustible material. Oxidation will take place at 300°F and will be most efficient between 400 and 650°F.

The physical units of a wet air oxidation plant are (*a*) an air compressor, (*b*) a sludge pump designed to pump against the desired pressure and auxiliary feed pumps, (*c*) a reactor to support the oxidation process, and (*d*) a series of heat exchangers to recover energy developed by the wet-burning of the sludge. The selection and sizing of these elements are the problems to be solved for the design of a plant using the principle of wet air oxidation for ultimate disposal of sludge.

Criteria for Unit Sizes

The sizes of the liquid pumping units are selected by the conventional parameter of volume of sludge to be treated.

The size of the reactor depends on the volumetric load, the desired operating temperature, the COD of the sludge entering the reactor, and the degree of COD reduction desired.

Figure 1 shows the change in reaction speed with increasing temperatures. At low temperatures (100 to 150°C) oxidation occurs at a slow rate and equilibrium is not reached in several hours. At temperatures in the

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

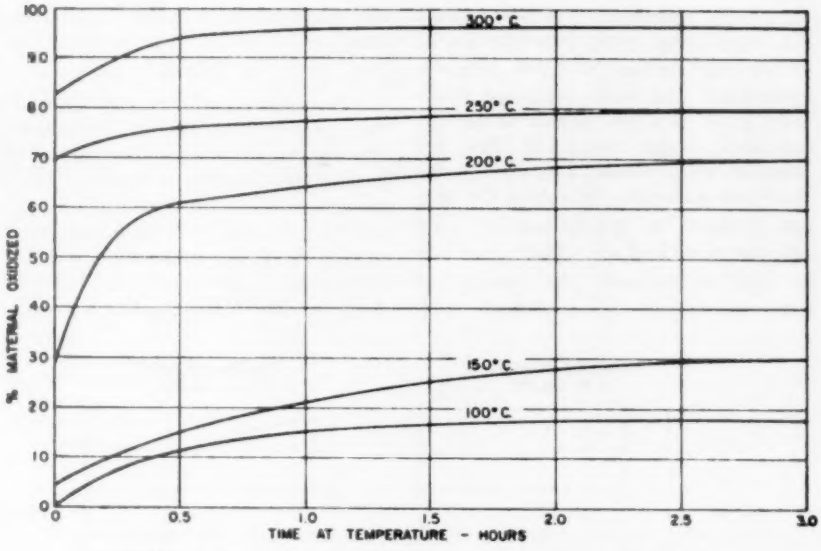

FIGURE 1.—Change in reaction speed with increasing temperatures.

range of 300°C oxidation is very rapid and equilibrium is reached in a matter of minutes.

Figure 2 shows the effect of temperature on the degree of oxidation of sewage sludges. In these tests the period of residence was constant at one hour and the temperatures and sludge concentrations were varied. The extent of oxidation, which is indicated by the residual COD, increases as the temperature of the reaction is increased. Also, within limits, the final COD is independent of the initial sludge concentration. Since the reaction time and COD removal are advantageously affected by increasing the temperature of reaction, the size of the reactor required will be smaller at higher operating temperatures.

The sizes of the heat exchangers are also a function of the volumetric load. Their sizes and number will, in a sense, determine the economy of the process since recovery of useful energy is a factor in the cost of degrading sludge.

The compressor should provide the exact amount of air to the reactor under the required pressure so that combustion will progress at a rate and temperature that will destroy the largest amount of organic matter or, if energy recovery is the purpose of combustion, to develop the most useful heat.

The quantity of oxygen required for degradation of sludge can be readily determined from the COD since the curve of utilization of oxygen from air by organic substances coincides very closely with the utilization of oxygen from chromate as determined by the COD procedure (1).

For purposes of the wet combustion method, it is convenient to consider the heat relationships in terms of the quantity of heat developed per pound of air when reacting with organic substances. These values for several organic substances are shown in Table I. When fuels are measured in the conventional terms of Btu per pound, hydrogen is the most compact fuel in the table. Oxalic acid is the poorest. However, when measured in terms of Btu developed per pound of air used to oxidize these fuels, the values are

more nearly constant. The pure chemicals vary from 1,220 Btu per pound of air for carbon to 1,780 Btu for hydrogen. The waste materials range from 1,270 Btu per pound of air for activated sludge to 1,410 Btu for chemical waste solids. The average for the waste materials, including the sewage sludges, is approximately 1,350 Btu per pound of air. This value can be used to estimate the amount of heat which will be developed when one pound of air reacts with sewage sludges.

Costs

The economy of the wet air oxidation process depends on the recovery efficiency of the energy developed. The energy developed is a function of the sewage solids concentration. The reactor of a small well-insulated system will be thermally sufficient with sludge as low as 2 per cent. In the units designed for Chicago, the power re-

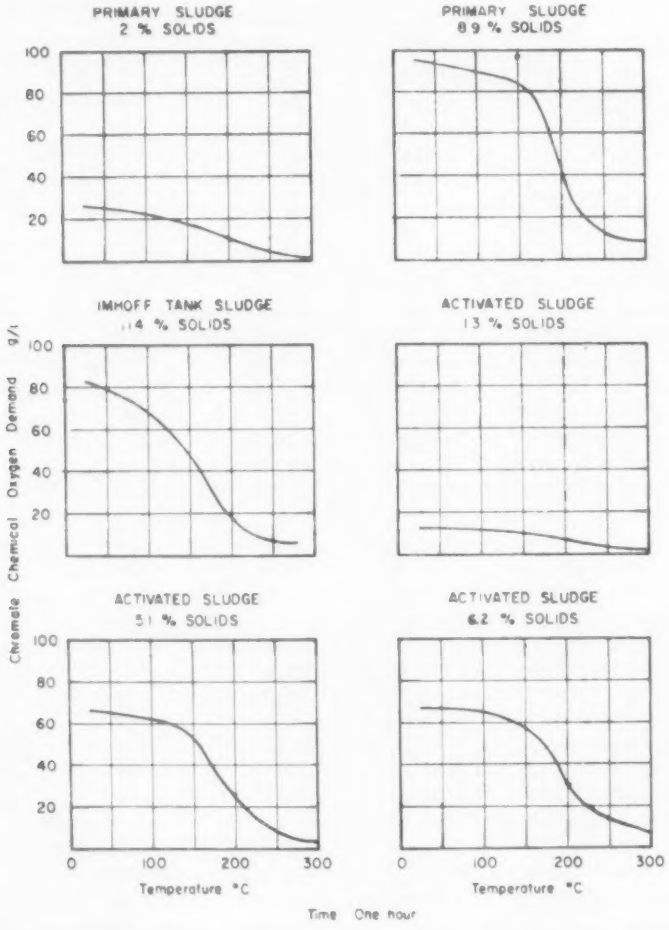

FIGURE 2.—Effect of temperature on the degree of oxidation of sewage sludges.

TABLE I.—Heat Characteristics in Oxidation of Typical Materials

Material	Heat Value (Btu/lb)	Oxygen Utilization (lb/lb material)	Air Utilization (lb/lb material)	Heat in Terms of Air Use (Btu/lb air)
Hydrogen	61,000	7.937	34.34	1,780
Ethylene	21,460	3.42	14.8	1,450
Carbon	14,093	2.66	11.53	1,220
Acetic acid	6,270	1.07	4.6	1,365
Oxalic acid	1,203	0.178	0.77	1,565
Pyridine	14,950	2.53	10.9	1,370
Fuel oil	19,376	3.26	14.0	1,380
Lactose	7,100	1.13	4.87	1,455
Casein	10,550	1.75	7.55	1,395
Waste sewage sludge solids	7,900	1.32	5.70	1,385
Semi-Chemical solids	5,812	.955	4.13	1,410
Sewage sludge, primary	7,820	1.334	5.75	1,365
Sewage sludge, activated	6,540	1.191	5.14	1,270

quired to degrade 50 tons of dry solids per day delivered to the reactor as 2-per cent sludge (approximately 70-per cent volatile) is 2,016 hp. The mixed gas from the reactor will develop 1,320 hp. Therefore, 696 hp will need to be purchased to complete degradation. If 4-per cent sludge can be furnished, 1,786 hp will be required of which 71 hp will need to be purchased. For 6-per cent sludge, 1,710 hp will be required and an excess of 180 hp will be developed. Figure 3 shows the cost of additional power required at one cent per kwhr. To treat a ton of solids furnished to the reactor as 2-per cent sludge will cost $2.50; with 3-per cent sludge, the cost is $1.20; with 4-per cent, $0.25; 4.4-per cent sludge is the break even point; 5-per cent sludge will furnish $0.35/ton of dry solids worth of power for other uses; and 6-per cent sludge will furnish $0.65/ton of dry solids of power for other uses. These values are for blower horsepower and pumping of sludge from the storage tanks to the reactor based on mixed gas turbine efficiency of 66 per cent. They do not include capital costs. Blower horsepower per ton of dry sludge is constant; pumping horsepower varies inversely with the sludge concentration. Capital costs for the reactor and heat exchangers also vary inversely with the sludge concentration since larger capacities must be provided for the larger liquid volumes handled. Recent work indicates that turbine efficiency will be as high as 72 per cent. In this case 3-per cent sludge will furnish enough energy to make up heat

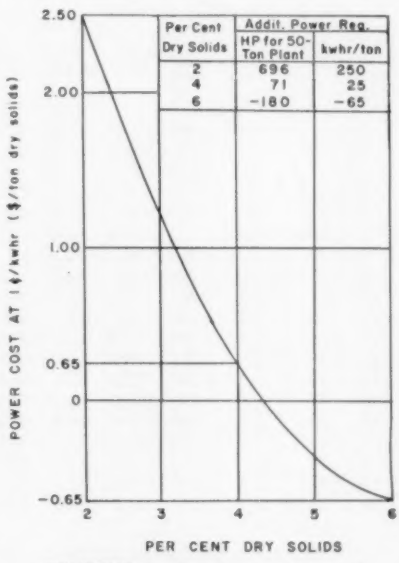

FIGURE 3.—Power cost for wet oxidation process.

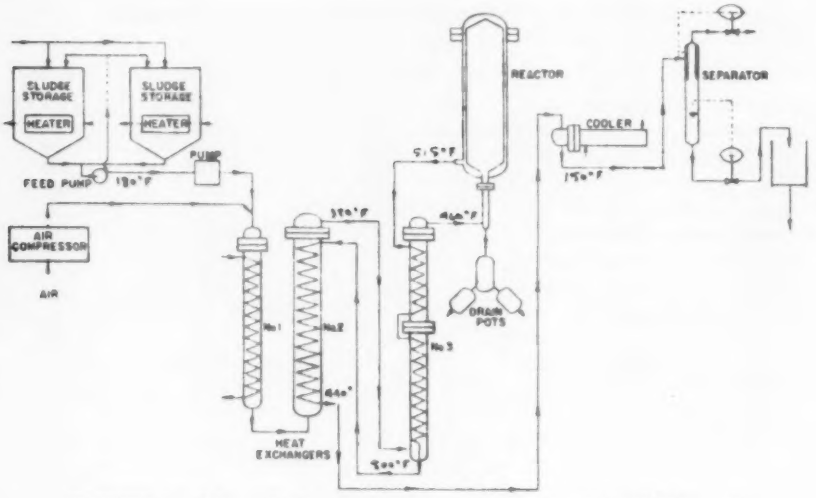

FIGURE 4.—Schematic flow sheet for two-ton per day wet oxidation unit.

losses from the reactor and power to operate the compressors. Power for the pumps, which is only a minor part of the power requirements, will need to be supplied from other sources. It is an advantage to thicken sludge to a concentration consistent with convenient handling.

TABLE II.—Operating Data for Wet Oxidation Process at West-Southwest Pilot Plant

Run No.	Duration of Run (hr)	Reactor		Feed						Effluent			Solids Treated (lb./day)
		Temp. (°F)	Pressure (psi)	Sludge (gph)	Air (lb./gal)	COD (g/l)	Solids (per cent)		Btu per lb	COD (g/l)	Solids (per cent)		
							Total	Volatile			Total	Volatile	
2	—	466	1,200	230.0	1.25	34.5	—	—	—	—	—	—	—
3	—	478	1,200	255.0	1.31	36.1	—	—	—	—	—	—	—
4	—	509	1,200	228.1	—	—	—	—	—	—	—	—	—
5	40.5	488	1,220	228.5	1.59	43.7	3.59	2.39	6,830	11.1	1.21	0.333	1,625
6	36	491	1,222	206.6	1.70	46.8	3.37	2.39	7,545	9.8	0.29	0.274	1,393
7	40	490	1,220	223.3	1.70	46.8	3.79	2.41	6,420	9.5	1.25	0.261	1,710
8	142	514	1,210	236.0	2.44	67.2	4.65	3.26	7,562	13.4	1.08	0.254	2,330
9	87	510	1,205	206.0	2.62	72.2	5.68	4.00	7,827	20.0	1.58	0.460	2,340
10	361	497	1,212	221.0	2.41	66.3	5.09	3.55	7,490	16.5	1.66	0.457	2,250
11	42	521	1,218	247.5	3.01	82.9	6.32	4.57	7,260	17.5	1.38	0.337	3,130
12	83	516	1,212	241.5	2.92	80.5	6.23	4.50	7,300	16.2	1.42	0.348	3,010
13*	32	501	1,214	228.2	3.47	95.6	7.65	5.52	7,460	26.2	3.37	1.095	3,500
14	40	511	1,200	217.0	2.24	61.8	5.09	3.43	7,400	11.4	1.66	0.352	2,210
15	37	510	1,210	214.0	2.21	60.8	5.12	2.93	5,450	10.6	2.32	0.299	2,180
16	32.5	507	1,202	253.0	2.40	66.2	7.45	4.24	5,240	12.7	3.81	0.601	3,770
17	52.5	519	1,216	244.8	2.19	60.2	5.16	3.29	7,050	11.1	1.57	0.361	2,560
18	26	502	1,205	251.0	1.70	46.7	4.21	2.63	6,375	9.7	1.88	0.395	2,120
19	31	515	1,209	233.0	2.24	61.7	6.05	3.63	—	13.8	1.96	0.355	2,830
20	19.75	511	1,205	211.0	2.18	60.1	4.45	2.93	—	10.7	1.32	0.232	1,880

* This run was not used in analyses of results. Concentrate discharged at high temperature and flashing occurred because of insufficient cooling capacity. Volumes are not correct; hence, extent of oxidation cannot be determined.

Pilot Plant Studies

In order to test the suitability of the wet air oxidation process for its needs, The Metropolitan Sanitary District of Greater Chicago operated a pilot plant designed to handle approximately two tons of sludge per day for a period of one year. Twenty runs were made extending in duration from 20 to 361 hr. The pilot plant unit (Figure 4) is 24 in. in diameter and approximately 30 ft high. Sludge preheated to 180°F by steam is pumped into two storage tanks with a capacity of 2,000 gal. A feed pump delivers the sludge at 30 to 50 psi to a high pressure pump. Immediately after passing through the pump, air is introduced into the stream from a compressor which has a capacity of 150 cfm at 1,200 psi. The sludge and air pass through a preliminary heat exchanger (No. 1) which is used only during the start-up period. It then flows through a second heat exchanger (No. 2), which raises the temperature of the air-sludge mixture to approximately 380°F, and finally through a third heat exchanger (No. 3) where the temperature is raised to 460°F. The heat exchangers are designed for flows up to 4 gpm.

The mixture then enters the bottom of the reactor, moves upward through a coarsely baffled path in the central body of the reactor and then spills over a port at the top of the inner shell into a jacket formed by the walls of the inner and outer shells. During the period of flow through the reactor, organic matter has undergone degradation by wet-combustion. The reaction is complete when the mixture spills through the port. The end products —steam, nitrogen, carbon dioxide, water, and ash—at approximately 515°F, pass through the bottom of the reactor into No. 3 and No. 2 heat exchangers where the sensible heat of the mixture is used to preheat the incoming sludge and air. The temperature is dropped to about 500°F in No. 3 heat

TABLE III.—Performance of Wet Oxidation Process at West-Southwest Pilot Plant

Volatile Solids Concentration Range (per cent)	No. of Runs	Average of Each Range													
		Feed (gph)	Air (lb/gal)	Pressure (psi)	Temp. (°F)	Influent			Effluent			Reduction			
						Total Solids (per cent)	Volatile Solids (per cent)	COD (g/l)	Total Solids (per cent)	Volatile Solids (per cent)	COD (g/l)	Total Solids (per cent)	Volatile Solids (per cent)	COD (per cent)
2.00–2.99	6	219	1.85	1,220	490	4.09	2.61	50.8	1.46	.299	10.2	64.3	88.5	79.9
3.00–3.99	5	244	2.31	1,208	508	5.21	3.43	63.4	1.59	.356	13.2	69.5	89.6	79.2
4.00–4.99	4	221	2.74	1,209	510	6.42	4.33	75.4	2.05	.436	16.6	68.1	89.9	78.0

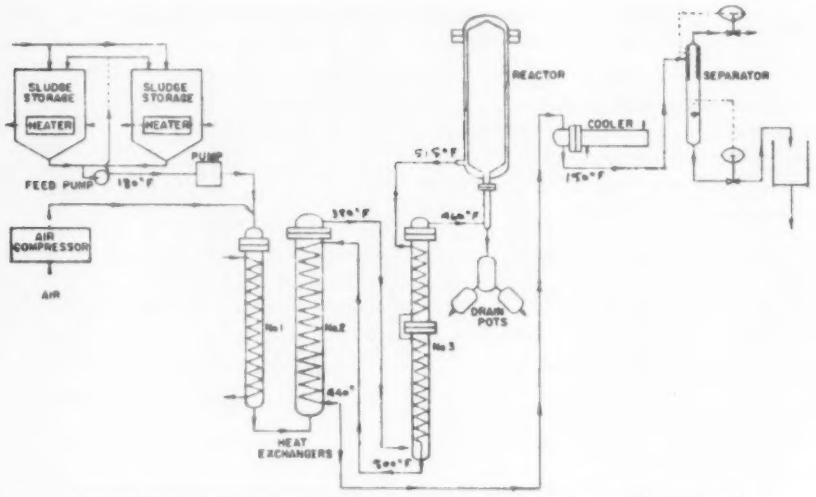

FIGURE 4.—Schematic flow sheet for two-ton per day wet oxidation unit.

losses from the reactor and power to operate the compressors. Power for the pumps, which is only a minor part of the power requirements, will need to be supplied from other sources. It is an advantage to thicken sludge to a concentration consistent with convenient handling.

TABLE II.—Operating Data for Wet Oxidation Process at West-Southwest Pilot Plant

Run No.	Duration of Run (hr)	Reactor		Feed						Effluent			Solids Treated (lb/day)
		Temp. (°F)	Pressure (psi)	Sludge (gph)	Air (lb/gal)	COD (g/l)	Solids (per cent)		Btu per lb	COD (g/l)	Solids (per cent)		
							Total	Volatile			Total	Volatile	
2	—	466	1,200	230.0	1.25	34.5	—	—	—	—	—	—	—
3	—	478	1,200	255.0	1.31	36.1	—	—	—	—	—	—	—
4	—	509	1,200	228.1	—	—	—	—	—	—	—	—	—
5	40.5	488	1,220	228.5	1.59	43.7	3.59	2.39	6,830	11.1	1.21	0.333	1,625
6	36	491	1,222	206.6	1.70	46.8	3.37	2.39	7,545	9.8	0.29	0.274	1,393
7	40	490	1,220	223.3	1.70	46.8	3.79	2.41	6,420	9.5	1.25	0.261	1,710
8	142	514	1,210	236.0	2.44	67.2	4.65	3.26	7,562	13.4	1.08	0.254	2,330
9	87	510	1,205	206.0	2.62	72.2	5.68	4.00	7,827	20.0	1.58	0.460	2,340
10	361	497	1,212	221.0	2.41	66.3	5.09	3.55	7,490	16.5	1.66	0.457	2,250
11	42	521	1,218	247.5	3.01	82.9	6.32	4.57	7,260	17.5	1.38	0.337	3,130
12	83	516	1,212	241.5	2.92	80.5	6.23	4.50	7,300	16.2	1.42	0.348	3,010
13*	32	501	1,214	228.2	3.47	95.6	7.65	5.52	7,460	26.2	3.37	1.095	3,500
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16	32.5	507	1,202	253.0	2.40	66.2	7.45	4.24	5,240	12.7	3.81	0.601	3,770
17	52.5	519	1,216	244.8	2.19	60.2	5.16	3.29	7,050	11.1	1.57	0.361	2,560
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TABLE III.—Performance of Wet Oxidation Process at West-Southwest Pilot Plant

Volatile Solids Concentration Range (per cent)	No. of Runs	Average of Each Range												
		Feed (gph)	Air (lb/gal)	Pressure (psi)	Temp. (°F)	Influent			Effluent			Reduction		
						Total Solids (per cent)	Volatile Solids (per cent)	COD (g/l)	Total Solids (per cent)	Volatile Solids (per cent)	COD (g/l)	Total Solids (per cent)	Volatile Solids (per cent)	COD (per cent)
2.00–2.99	6	219	1.85	1,220	490	4.09	2.61	50.8	1.46	.299	10.2	64.3	88.5	79.9
3.00–3.99	5	244	2.31	1,208	508	5.21	3.43	63.4	1.59	.356	13.2	69.5	89.6	79.2
4.00–4.99	4	221	2.74	1,209	510	6.42	4.33	75.4	2.05	.436	16.6	68.1	89.9	78.0

exchanger and to about 440°F in No. 2 heat exchanger. The mixture then flows through a water cooler where there is a further drop in temperature to 150°F and finally through a separator. In the separator, the gases are vented to the atmosphere and the liquid effluent, containing the ash, is withdrawn continuously from the bottom of the separator.

Table II shows the detailed operating data for the individual runs. Runs 1 through 4 were in the nature of a "shake-down" operation. No samples were collected. Difficulties caused by insufficient heat exchanger capacity developed in Run 13. This run was not used in the statistical analysis given in Table III.

This table describes the performance of the pilot plant runs. The data are grouped according to their volatile solids concentration which ranged from 2.39 to 4.57 per cent and averaged 2.61, 2.39, and 4.33 per cent for the three groups.

The parameters that best indicate the effectiveness of the wet-oxidation system are the reduction of COD, which measures the degree of oxidation accomplished, and the reduction of volatile solids.

Within the ranges of the volatile solids concentrations studied, the reduction of oxidizable material as measured by the COD was 79 per cent. The amount of volatile solids destroyed was 89 per cent. Total solids reduction averages 67.3 per cent.

The results confirm the observation that the degree of sludge degradation is a function of the temperature and does not vary appreciably in percentage because of variations in solids concentration. Under the operating conditions of the pilot plant, 500°F and 1,200 psi, this was fairly constant at 79-per cent COD and 89-per cent volatile solids. These results would be improved at higher operating temperatures.

Chemical Characteristics of End Products

Table IV shows a partial analysis of the reactor effluent. The effluent is characterized by high ammonia and high volatile acid which result from the oxidation of the nitrogen and carbon constituents of the sludge. The BOD of the effluent ranged from 5,400 to 8,400 mg/l and represents a reduction of about 60 per cent from the BOD of the original liquid sludge. The settleable ash is between 10 and 12 per cent of the volume after one hour settling time. The residual COD left in the ash from the effluent ranged from 1,900 to 5,000 mg/l and BOD from 530 to 1,350 mg/l. The volatile content of the dried ash ranged from 13 to 17 per cent with an average of

TABLE IV.—Chemical Characteristics of Reactor Effluent

Volatile Solids Concentration Range (per cent)	Average of Each Range									
	Reactor Effluent					Settled Effluent		Effluent Ash		
	NH_3—N (mg/l)	Org. N (mg/l)	Volatile Acids as Acetic (mg/l)	BOD (mg/l)	COD (mg/l)	BOD (mg/l)	COD (mg/l)	Volume Settled in 1 hr (ml/l)	BOD* Left in Ash (mg)	COD* Left in Ash (mg)
2.00–2.99	1,370	368	3,200	5,420	10,200	4,890	8,300	98	530	1,900
3.00–3.99	1,625	425	3,480	7,030	13,200	6,410	9,800	105	620	3,400
4.00–4.99	1,640	548	3,980	8,460	16,600	7,110	11,600	116	1,350	5,000

* BOD and COD left in ash settled from one liter of reactor effluent (by difference, reactor effluent-settled effluent).

TABLE V.—Typical Spectrometric Analysis of Ash from Run No. 9

Determination	Per Cent
Iron	4.92
Silicon	3.78
Potassium	0.76
Manganese	0.025
Calcium	0.87
Aluminum	3.90
Zinc	0.04
Copper	0.24
Magnesium	0.03
Phosphorus	2.62
Boron	0.03
Nickel	0.01
Sodium	0.12
Specific gravity	2.23

15 per cent. Table V shows the results of a spectrometric analysis of the dried ash. The mineral content is characteristic of the ash from a highly industrialized area. The effluent is discharged from the reactor as a sterile liquid. The ash is biologically stable.

Table VI shows the analysis of the gas exhausted from the system. The gas content is mainly nitrogen and carbon dioxide. The residual oxygen is left in the exhaust gases deliberately in order to assure complete combustion. There is a trace of hydrocarbons. The gases are not expected to cause air pollution problems since they carry no fly ash and exhibit only a slight odor of pyridine.

TABLE VI.—Mass Spectrometer Analysis of Exhaust Gas

Determination	Per Cent by Volume
Hydrocarbons	<0.02
Hydrogen	0.4
Nitrogen	82.8
Oxygen	2.0
Argon	0.9
Carbon dioxide	13.9

Supplementary Treatment of Reactor Effluent

The effluent responds readily to treatment by aerobic biological processes. Table VII gives the results of a laboratory experiment designed to determine if the effluent from the wet oxidation process could be returned to the aeration system. The experiment indicates that there would be no de-

TABLE VII.—Treatment of Reactor Effluent by Activated Sludge in a Laboratory Experiment *

Aeration Period (hr)	BOD		Mixed Liquor Solids				pH	
			Beginning of Period		End of Period			
	Sewage Mixture (mg/l)	Effluent (mg/l)	SS (mg/l)	Ash (per cent)	SS (mg/l)	Ash (per cent)	Beginning of Period	End of Period
4.5 (1st period)	311	45	3,490	29.2	3,620	26.5	8.2	8.4
4.5 (2nd period)	308	22	3,540	27.2	3,650	23.8	8.3	8.5
4.5 (3rd period)	355	21	3,250	26.1	3,470	24.5	8.3	8.6
8 (4th period)	348	9	2,900	25.9	2,900	21.9	8.3	9.6

* The wet-oxidation effluent was proportioned to the raw sewage on the basis of 600,000 gal of 6-per cent sludge per day (150 tons dry) to 800 mgd sewage plus 50 per cent return sludge. Effluent-sewage mixtures were aerated for time shown, then allowed to settle ½ hr. Supernatant was siphoned off and replaced with fresh amount of effluent-sewage mixture. None of the sludge was removed.

TABLE VIII.—Performance of Wet Oxidation Process at High Pressures *

Item	1,500† psi Pressure			1,800‡ psi Pressure		
	Max.	Min.	Avg.	Max.	Min.	Avg.
Feed (gph)	228	100	142	183	102	129
Air (lb/gal)	1.8	1.46	1.61	1.95	1.73	1.80
Pressure (psi)	1,550	1,500	1,525	1,825	1,810	1,820
Temp. (°F)	540	493	524	541	525	530
Influent						
Total solids (%)	3.57	2.86	3.29	3.52	3.46	3.48
Volatile solids (%)	2.25	1.91	2.16	2.49	2.22	2.31
COD (g/l)	49.6	40.2	44.5	53.9	47.8	49.8
Effluent						
Total solids (%)	1.42	0.69	1.14	1.04	0.76	0.92
Volatile solids (%)	0.36	0.15	0.24	0.21	0.11	0.17
COD (g/l)	12.0	6.9	9.3	9.3	7.5	8.1
Reduction (%)						
Total solids	80.0	46.8	65.4	78.1	70.4	73.6
Volatile solids	93.0	83.3	88.6	95.0	90.4	92.4
COD	85.6	72.6	79.3	86.4	82.8	85.1

* Tests performed at Salvo Chemical Company, Rothschild, Wis.
† Test consisted of 10 runs at average pressure of 1,525 psi (range from 1,500 to 1,550 psi).
‡ Test consisted of 3 runs at average pressure of 1,820 psi (range from 1,810 to 1,825 psi).

terioration of the activated sludge plant effluent. Final effluent in the range of 10 to 20 mg/l BOD, common to activated sludge, resulted. Laboratory trickling filters gave similar results.

High Pressure Tests

A series of tests was made at pressures in the range of 1,500+ and 1,800+ psi in a reactor 11 in. in diameter and 20 ft high. The temperature range at the 1,500+ pressure was 493 to 540°F, averaging 524°. At the 1,800+ pressure, the temperature range was 525 to 541°, averaging 530°. The results of these tests are shown in Table VIII. The sludge solids used ranged from 2.86 to 3.57 per cent; volatile solids were 1.91 to 2.49 per

TABLE IX.—Chemical Characteristics of Reactor Effluent from High Pressure Treatment

Item	1,500 psi Pressure*			1,800 psi Pressure*		
	Max.	Min.	Avg.	Max.	Min.	Avg.
Temp. (°F)	540	493	523	541	525	530
NH_3 (mg/l)	1,760	1,008	1,410	1,750	1,050	1,490
Volatile acids as acetic acid (mg/l)	4,600	3,500	3,930	4,200	3,300	3,830
pH	7.1	5.1	6.1	6.8	5.6	6.3
COD (mg/l)	12,000	6,900	9,300	9,300	7,500	8,100
Settled effluent COD (mg/l)	9,900	6,500	7,620	7,800	6,500	7,030
Volatile content in effluent residue settled 1 hr (ml/l)	175.0	70.0	108	—	—	—
COD in residue settled 1 hr (mg)	4,800	400	1,550	1,000	900	967

* Same ranges as reported in Table VIII.

cent; and COD from 40.2 to 53.9 mg/l. The average reduction in volatile solids at the 1,500+ pressure was 88.6 per cent and the COD reduction was 79.3 per cent. The reductions were in the same range as those at 1,200 psi. However, the experiments showed that it was possible to operate at a much higher feed rate at 1,500+ psi than at 1,200+ psi without any significant deterioration of the effluent. Significantly better results were obtained at 1,800+ psi. The reduction in volatile solids at this pressure was 92.4 per cent and the COD reduction was 85.1 per cent.

The reactor effluent from the higher pressure systems is similar to that obtained at 1,200+ psi (Table IX). It is characterized by high ammonia and high volatile acids. The COD of the liquid portion is lower than that of the 1,200 psi system as is the COD remaining in the ash.

Design Features of Full Scale Plant

These pilot plant studies were used to design a full scale plant.

Experience has indicated that the demand for heat-dried activated sludge has about reached the peak and is leveling off. At times during the off-season in the fertilizer industry, disposal of the present output is difficult. There have also come on the fertilizer market, large quantities of other organics which are competitive with activated sludge. It is conceivable that some time in the future the demand for the heat-dried product will not be able to absorb the production. Therefore, to expand the existing system to produce more heat-dried sludge would not be practical.

Serious thought and consideration were given to anaerobic digestion. But here again there are problems of disposal of an additional 200,000± cu yd/yr of digested sludge above the 180,000 cu yd now produced at the West Side Plant.

This problem could be solved only by a system that resulted in ultimate disposal of sewage solids and left a residue which was compact and devoid of any nuisance-causing charac-

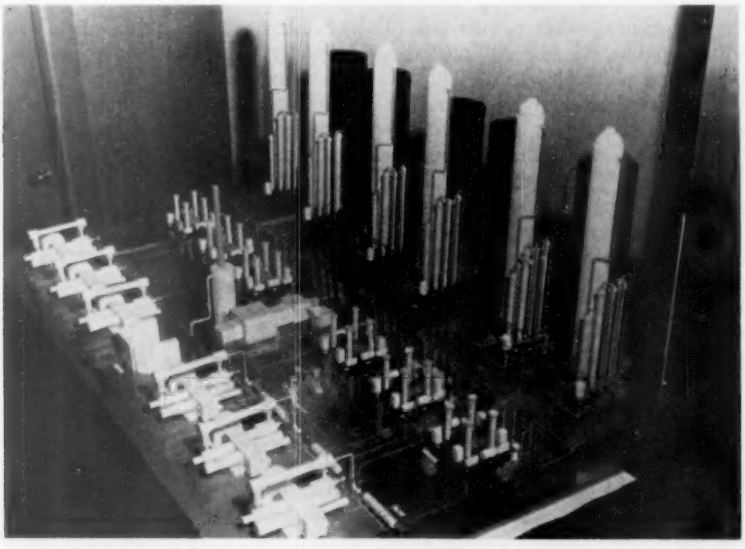

FIGURE 5.—Model of the six-unit plant originally planned for Chicago.

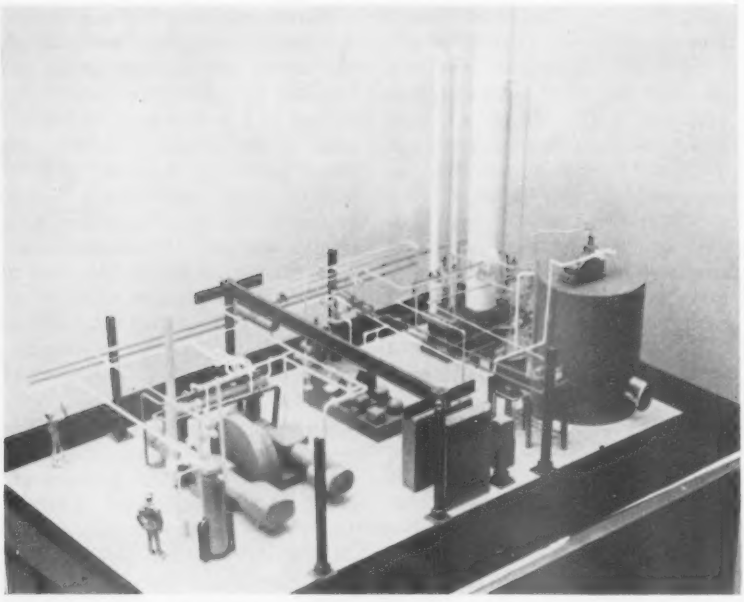

FIGURE 6.—Model of the 5.6-ton plant designed for Wheeling, W. Va.

teristics. These qualities appear to have been met by the wet air oxidation system.

The Metropolitan Sanitary District of Greater Chicago has contracted to spend approximately $13 million for a wet oxidation plant to handle 200 dry tons/day of sewage solids at 3-per cent concentration. Of this amount $11,780,000 will be for purchase and erection of reactors, compressors, high pressure pumps, and other components of the wet oxidation unit. The remainder is for foundations, buildings, etc.

The plant to be constructed at the West-Southwest Works of the Metropolitan Sanitary District of Greater Chicago will consist of 4 individual units, each with a capacity of 50 dry tons/day of sewage solids at 3-per cent concentration.

There will be 4 air compressors, one for each unit. These will be reciprocating, 5-stage compressors, each with a capacity for compressing 4,800 cfm of free air to a pressure of 1,850 psi. Each compressor will be driven by a 2,250-hp synchronous motor at 327 rpm.

Sludge will be pumped to the reactor by 8 high pressure pumps, two per unit, each with a rated capacity of 160 gpm at a discharge pressure of 1,850 psi. Design pumping rate is 273 gpm at 3-per cent solids. The high pressure pumps will be fed by centrifugal sewage pumps, one per unit.

There will be 1 reactor and 6 heat exchangers per unit. The reactor will be 61 ft 8 in. high, and 78 in. ID. The shell will be stainless clad, 4½ in. thick. The inner stainless lining will be 10-gage stainless 316. The reactor will be designed for pressure of 1,800 psi at 600°F. The weight of each reactor will be 160 tons.

The heat exchangers will be 1½ in. in diameter and 26 ft long. There will be a total of approximately 3,000 sq ft of heating surface per unit.

Sludge will be stored in tanks 20 ft high and 20 ft in diameter with a capacity of approximately 47,000 gal. Each storage tank will be equipped with a heating coil to heat the sludge to 90°F. There will be one tank for each unit.

All four units will be controlled automatically from a control instrument room.

The vapors from the process will be expanded through a mixed gas turbine rated at 12,500 kw with a power factor of 1.0. The turbine exhaust will go, at atmospheric pressure, to a contact cooler 9 in. in diameter by 13 ft 6 in. high.

The building to house the pumps, compressors, and other appurtenances will be 94 by 162 ft. The reactor, heat exchangers, and storage tanks will not be housed.

The whole plant will cover 25,000 sq ft.

Figure 5 shows a model of the 6-unit plant originally proposed. The contract is for four units.

Figure 6 shows a model of the 5.6-ton plant now being designed for Wheeling, West Virginia.

Acknowledgments

The authors wish to express their appreciation to the staffs of The Metropolitan Sanitary District of Greater Chicago and Salvo Chemical Company which assisted in operating the pilot unit and obtaining the chemical data reported herein. They are also indebted to C. McLaughlin, Engineer of Mechanical Design for the Sanitary District, who acted as coordinator for the experimental work; Burton A. Scheidt, Chief Engineer for the Sanitary District; to F. J. Zimmermann, the inventor, and to his associates on the executive staff of Sterling Drug Company; and to the President of the Board of Trustees of the Sanitary District and his eight associates, who made possible by their support the performance of the pilot plant tests.

Reference

1. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes." 10th Ed. Amer. Pub. Health Assn., New York (1955).

NATIONAL CONFERENCE ON WATER POLLUTION

More than 1,000 leaders representing some 300 national groups and organizations will meet December 12–14, 1960, at the Sheraton-Park Hotel in Washington, D. C. to attack the critical water pollution problem. This conference is the first of its kind and is being called at the direction of President Eisenhower and of Secretary of Health, Education, and Welfare Arthur S. Flemming.

Among the organizations represented will be municipal, state, interstate, and federal organizations and agencies; industrial, farm, and labor groups; civic clubs and associations; fish, game, and boating associations; and organizations in the fields of recreation, conservation, engineering, public health, and scientific research. Vice-President Ray E. Lawrence is representing the Federation on the Steering Committee, which is planning the details of the conference.

It is hoped that this meeting will do much to build a national program against water pollution and to mobilize public opinion behind such a program.

EFFECT OF DETENTION TIME ON ANAEROBIC DIGESTION

By Ervin Hindin and Gilbert H. Dunstan

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In a previous paper (1) the effect of loading rates on the chemical indexes of anaerobic sludge digestion was discussed. This phase of the over-all study was initiated to determine the effect of detention time on the anaerobic digestion of raw sludge.

The experimental apparatus used was the same as that described in the earlier paper (1).

Experimental Procedure

Ten liters of digesting sludge obtained from the primary digester at the Pullman, Washington, sewage treatment plant were placed in the laboratory scale digesters. One-half the computed volume of raw sludge needed for a detention time of 90 days and a loading of 0.075 lb of volatile solids per cubic foot of digester capacity per day was added initially. The volume was gradually increased so that after five weeks the digesters were being fed the computed volume of raw sludge. After the digesters had reached a point of "dynamic equilibrium" the supernatant, the digested sludge, and digester gas were routinely analyzed for their chemical characteristics.

A loading of 0.075 lb of volatile solids per cubic foot of digester capacity per day was maintained throughout this study. The detention times selected for study were 5, 10, 20, 30, 60, and 90 days.

For a detention time of 30 days or longer, the digesters were fed once daily. For detention times of less than 30 days, no more than 1/30 of the capacity of the digester was added at one time. If feedings were more than once daily, the addition of raw sludge to the digesters was scheduled so as to be made at equal time intervals.

The supernatant was collected and tested for alkalinity, volatile organic acids, ammonia nitrogen, biochemical oxygen demand, and settleable solids. These were determined by the procedures of "Standard Methods" (2). Separation of the volatile acids was facilitated by using partition chromatographic procedures of Bulen (3) and modified by Teletzke (4), and the equipment described in the Bulen modification by Mueller, Buswell, and Larson (5).

The volume of digester gas was measured prior to feeding. An Orsat type instrument was used to measure the relative amounts of certain gases. The digester gas was first bubbled through an acidic arsenic trichloride solution, then through concentrated potassium hydroxide. The gases absorbed by the acid arsenic trichloride solution, consisting mainly of hydrogen sulfide and volatile organic sulfides, are designated as the hydrogen sulfide group. The gas, void of the hydrogen sulfide group, absorbed by the concentrated caustic was classified as those of the carbon dioxide group.

Raw Sludge

The feed consisted of solids settled from the raw sewage and the cellular material sloughed off from a high-rate

trickling filter. The raw sludge was a domestic sludge, free of any industrial wastes.

Raw sludge was obtained weekly. Since sludge is a heterogeneous mixture of settleable sewage solids and associated microorganisms, it is probable that the nutritional composition of the feed was not always the same even though the volatile solids remained the same. The raw sludge obtained contained at least 5.4 per cent total solids of which 73 ± 3 per cent was volatile.

Upon storage at 4°C up to 7 days, there was no change in the volatile solids, pH, little change in the alkalinity, and little in the volatile organic acids.

Results and Discussion

Data

The data presented in the following illustrations are average values of the chemical indexes obtained over a minimum testing period of five weeks.

The maximum detention time examined in this study was the 90-day level. Although this level is in excess of that commonly used in single-stage digesters, conditions did approach that of complete decomposition.

The supernatant liquor was allowed to settle for one hour, after which the liquid portion was examined for its chemical characteristics. At the 90-day detention time level, 12 per cent of the supernatant had a tendency to settle. The solids were granular and had a tendency to settle rapidly. The milky white supernatant liquor showed a pH of 7.51, total alkalinity of 4,991 mg/l as $CaCO_3$, total volatile organic acids of 37 mg/l as acetic acid, ammonia nitrogen of 1,215 mg/l as N, and a BOD of 1,464 mg/l. The slight amount of odor present from the liquor was not objectionable.

The quantity of gas produced was 3.90 cu ft per pound of volatile matter added per day. The carbon dioxide group content of the gas was 25.5 per cent and that of the hydrogen sulfide group, 7 per cent. The gas was combustible and the odor due to organic sulfides and amines was faintly noticeable.

The digested sludge had a tarry odor, dewatered readily, and had a pulverulent texture when dried. The volatile solids content of the sludge was 29 per cent. The rate of reduction obtained at this detention time was 86 per cent of the volatile matter added per day. This rate of reduction approached 90 per cent, at which point digestion is technically completed (5).

Effect of Detention Time

With a decrease in detention time, a change in the chemical characteristics of digestion was anticipated due to the availability of more bacterial food. A decrease in detention time would decrease the time allowed for the complete decomposition of complex organic matter and reduce the time for the intermediate products to be metabolically transformed to stable end products. Unstable conditions will exist until the microorganisms have become fully adapted to their new environment.

There are two conditions which must be considered in evaluating a decreased detention time: (*a*) the availability of more bacterial food, and (*b*) the decrease in time for the flora to consume or stabilize the complex organic matter.

The anaerobic digestion process will aim to produce substances which are metabolically inert as gases and soluble and insoluble inorganic residues. The rate and nature of the bacterial metabolism of sewage sludge are affected to a large extent by the presence and magnitude of the various intermediate and final products. Thus, there is a great interdependency of one product on another.

With a decrease in detention time, there was undoubtedly an increase in

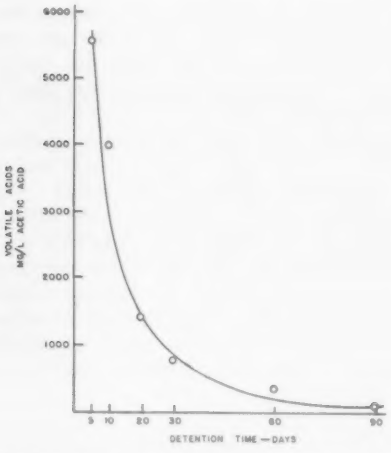

FIGURE 1.—Relationship of total volatile acids to detention time.

bacterial activity. The volatile organic acids, intermediate products of anaerobic digestion of all organic matter, increased as the detention time decreased as illustrated in Figure 1. Alkalinity, caused in part by intermediate products, decreased as the detention time decreased as shown in Figure 2.

Ammonia nitrogen, the chief cationic constituent responsible for the alkalinity, decreased at a greater rate than the alkalinity as shown in Figure 3.

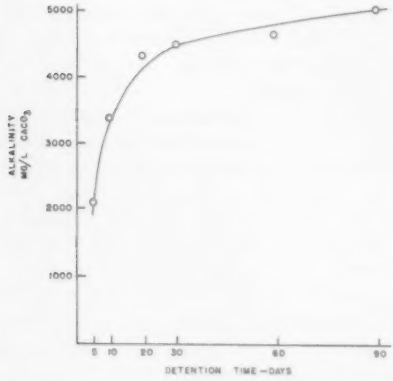

FIGURE 2.—Relationship of alkalinity to detention time.

There are a number of factors which affected the ammonia nitrogen content at the respective detention times. As the environment becomes more acid, certain bacteria—especially those of the family enterobacteriaceae—will change their amino acid metabolism; *i.e.*, by decarboxylation rather than deamination. Another possibility is that time allowed for the degradation and liquefaction of the complex proteinaceous solids is insufficient; hence, there is an increase in partially decomposed amino acid-like product in the supernatant.

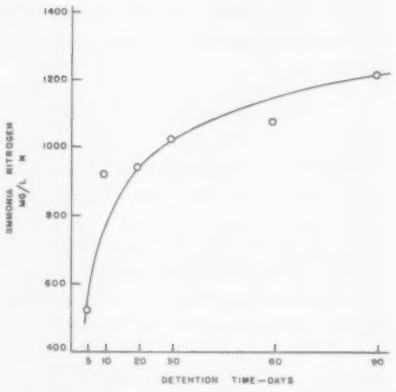

FIGURE 3.—Relationship of ammonia nitrogen to detention time.

Buffering System

The primary buffering system in the anaerobic digestion of sewage is the ammonium bicarbonate-carbon dioxide system. Ammonium nitrogen and carbon dioxide are final products of digestion; in a closed system, carbon dioxide is not the limiting material. Thus, the following system will exist:

$$NH_4^+ + CO_2 + H_2O \rightleftarrows NH_4^+ + H_2O + HCO_3^- \quad (1)$$

Since this reaction is reversible, the relative concentration of ammonium ion to the dissolved carbon dioxide will determine the direction the equilibrium will shift. The presence of free vola-

tile acids will affect the system as follows:

$$NH_4^+ + HCO_3^- + H_2O + R—COOH \rightarrow R—COO^- + NH_4^+ + 2H_2O + CO_2\uparrow \quad \ldots\ldots (2)$$

where R—COOH represents the volatile acid molecule.

Since carbonic acid is a weaker acid than the volatile organic acids, this reaction is irreversible. If the concentration of the free volatile organic acids is equal to or less than the cations available in the buffering system, there will be little or no change in the system. However, if the concentration of the volatile acids exceeds that of the concentration of the cationic components of the alkalinity, free volatile organic acids will be present. The value of the hydrogen ion concentration of the supernatant liquor once the buffering system has been disrupted, will depend on the relative rates of production and destruction of the volatile acids and the formation of alkaline products. Figure 4 illustrates the various phases the buffering system went through as reflected by the pH.

The soluble organic material in the supernatant as measured by the five-day BOD increased as the detention time decreased owing to the higher concentration of the intermediate products (Figure 5).

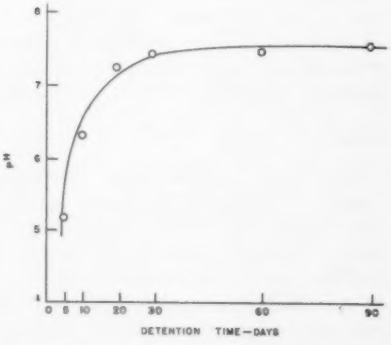

FIGURE 4.—Relationship of pH to detention time.

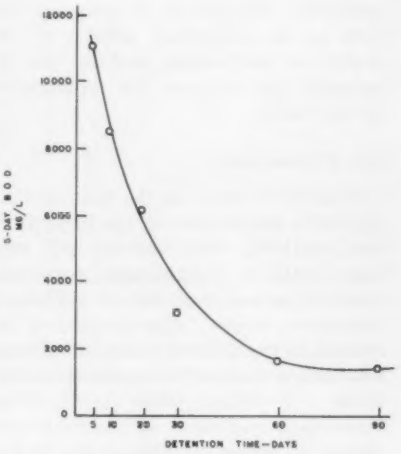

FIGURE 5.—Relationship of BOD to detention time.

Sludge

The raw sludge used in this study contained between five- and six-per cent solids while the remainder of the material was loosely bound water. The raw sludge having great lyophilic properties will settle little even when stored for a few days. The lyophilic characteristic is mainly attributed to the proteins and other colloidal matter. During the anaerobic digestion, the proteins are degraded to soluble polypeptides or amino acids, and the colloids are thus decomposed. This will change the water affinity characteristics of the sludge and thus most of the loosely bound water will be released. A lesser quantity of water will result as a product of the liquefaction and decomposition of the complex material. The per cent of settleable solids found in the supernatant will vary with the time allowed for decomposition. At the 90-day detention time level, the settleable solids showed strong lyophobic properties. At the 60- and 30-day detention time levels, weak lyophobic characteristics existed. At detention times of 20 days or less, lyophilic conditions were present, increasing as the detention time de-

creased. This linear increase is due both to the increasing affinity of the sludge to hold water and by the decreased time allowed for liquefaction of the solids.

Gas Production

With an increase in the intermediate products, an increase in the final products resulted. The increase will continue until the formation of toxic material or an accumulation of inhibitory substances occurs. Gas production increased as the detention time decreased. Production reached a maximum at the 20-day detention time level after which a rapid rate of decrease occurred as shown in Figure 6. It has been shown that when the volatile organic acid content exceeds 2,000 mg/l as acetic acid, the acids themselves exhibit an inhibitory effect on the methanogenic microorganisms (6). A sharp decrease in gas production was noted at the 17-day detention time level when the volatile acids were 2,000 mg/l as acetic acid.

The carbon dioxide and the hydrogen sulfide group content of the gas increased as the detention time increased as shown in Figure 7. The rate of increase in the carbon dioxide and the hydrogen sulfide group content was slight up to the 20-day detention time level, after which the relative quantity of these components rose rapidly. If there is a rise in the volatile acids content without an equivalent rise in the alkaline products production, the remaining free acids will react with the cationic components of the buffering system. As the bicarbonate ion is a major constituent of the buffering system, the neutralization of the acids will produce carbon dioxide as one of its products. Assuming that the digesting liquid is saturated with carbon dioxide, the excess carbon dioxide will enter into the gas collection system. The mechanism of hydrogen sulfide production is more complicated but is somewhat similar to that of the carbon dioxide production.

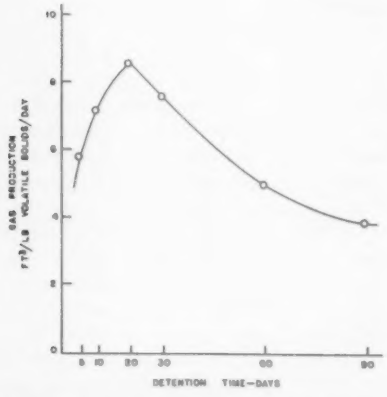

FIGURE 6.—Relationship of gas production to detention time.

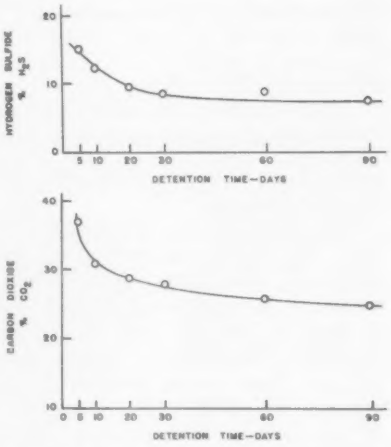

FIGURE 7.—Relationship of component gases to detention time.

Odor

The odor of the gas attributed mainly to amines and organic sulfides was faintly noticeable at the 90-day level. The odor increased slightly at the 60- and 30-day levels. However, at the 20-day detention level, a much stronger odor was noticed and increased to where, at five days, it was extremely strong. The marked in-

crease in odor may be attributed to two factors. As the amines and organic sulfides are intermediate products, they will be decomposed to the final or simpler intermediate products, provided the microorganisms have sufficient time. The other factor which will affect the rate of production of the amines and organic sulfides is the difference in the direction of the metabolism, of an alkaline environment from an acidic environment. In an alkaline environment which existed in the digester up to the 18-day detention time level, microorganisms as *E. coli* will attack amino acids by deamination and liberate ammonia nitrogen and acid products. In an acid condition which existed at detention times of 18 days or less, decarboxylation of amino acids will occur, liberating carbon dioxide and alkaline amine products.

The gas was combustible at all detention time levels except the 10- and 5-day levels. At the 10-day level, occasional difficulty was encountered in igniting the gas, while at the 5-day level the gas did not ignite.

Volatile Solids

The most important end product of digestion from the standpoint of disposal is that of the digested sludge. Sludge containing over 40-per cent volatile solids had a fibrous texture, possessed an objectionable odor, and dewatered slowly. As the relative

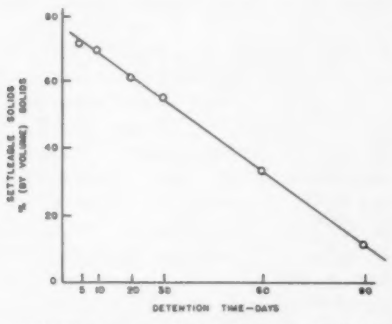

FIGURE 8.—Relationship of settleable solids to detention time.

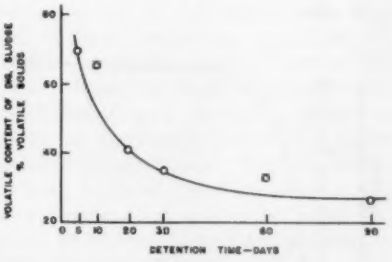

FIGURE 9.—Relationship of volatile content of digested sludge to detention time.

quantity of the volatile matter in the digested sludge increased the more objectionable it became. The per cent of volatile solids remaining in the digested sludge is to a large extent a function of the length of time allowed for the decomposition of the raw sludge (Figure 8). As the length of the detention time decreased, the per cent of volatile matter increased as illustrated in Figure 9. The rate of increase in the volatile solids content is slight between the 90-day and 30-day detention time levels, increasing from 29 to 35 per cent of volatile solids in the digested matter. Beyond the 30-day detention time level the volatile content of the digested sludge rose almost linearly. At the 5-day detention time level the volatile content of digested sludge was within the lower limits of the raw sludge.

As the digester efficiency is a measure of the destruction of the volatile matter it was expected that efficiency would decrease as the detention time decreased. This is illustrated in Figure 10. Decreasing the detention time from 90 to 30 days had slight effect on the digester efficiency. The change was 3.5 per cent. An 86-per cent reduction of the volatile matter added was attained at a detention time of 90 days. At detention time levels of less than 30 days, a rapid decrease in the per cent reduction did occur. There is a practical limit to the degree of digestion of any raw sludge. The minimum detention time at which this

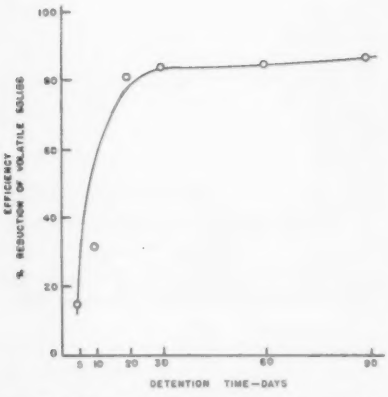

FIGURE 10.—Relationship of volatile solids reduction to detention time.

limit is reached may be regarded as the critical point of detention as far as digester efficiency is concerned. An increase in detention would only serve as a safety factor. The practical degree of efficiency, 83-per cent reduction in volatile solids added, occurred at the 30-day level. The data confirm the accepted criteria that active digestion of raw sludge in a single-stage, non-mixing digester ceases in about a month (7).

Organic Acids

Butyric, propionic, and acetic acids were found in preponderance during the normal digestion of sewage solids. The three major acids did exceed 96 per cent of the total volatile acids at all detention times except that at 90 days. At the 90-day level, the major acids comprised 65 per cent of the total acids with acetic acid comprising over 90 per cent of the total of the three.

Formic and lactic acids varied little in their concentrations regardless of the detention level. At detention times greater than 60 days, formic and lactic acids comprise an appreciable portion of the total organic acids present. At detention times less than 60 days, relative amounts of these acids are found in trace quantities.

A decrease in detention time from 90 days to the 60-day level brought about a decrease in the relative quantity of acetic acid and an increase in propionic and butyric acids. The rate of change from the 60- to 30-day detention time was slight while the rate of change was rapid at detention times less than 30 days.

Each lot of raw sludge used in this study was examined for the three major acids and the supernatant from a "sour" digester was examined for the relative quantity of the individual volatile organic acids. According to Table I, the relative quantity of the butyric, propionic, and acetic acids after 15 days detention was the same as that found in raw sludge and the supernatant from the "sour" digester.

The relative quantities of acetic, butyric, and propionic acids have an effect on the quality of the gas. Stadtman and Barker have shown that

TABLE I.—Distribution of Component Volatile Acids

Detention Time (days)	Butyric Acid (per cent)	Propionic Acid (per cent)	Acetic Acid (per cent)	Formic Acid (per cent)	Lactic Acid (per cent)
90	2.56	3.23	59.31	20.84	14.06
60	9.88	23.23	63.05	2.11	1.24
30	9.49	28.00	61.66	0.54	0.33
20	15.00	36.17	45.56	0.67	0.60
10	24.85	35.78	38.55	0.51	0.31
5	25.17	39.91	34.10	0.43	0.40
Avg raw sludge	19.95	32.19	41.99	—	—
Sour digester	18.68	36.90	43.89	—	—

methane may be formed either by the reduction of carbon dioxide by compounds capable of supplying hydrogen atoms, or the anaerobic decomposition of acetic acid (8)(9)(10). The mode of methane production will depend on the microorganisms present and the type of digestible organic material available. They have also shown that, if carbon dioxide is present in the solution, the microorganisms will produce a gas of a higher methane to carbon dioxide ratio from propionic or butyric acids than from acetic acid. The change in the relative quantities of butyric, acetic, and propionic acids at detentions of or less than 60 days, indicates that the rate of consumption of propionic and/or butyric acid occurred at a slower rate than that of acetic acid. A digester gas of a higher carbon dioxide content would be produced with an increase in total volatile acids and a decrease in the relative amount of acetic acid. This did occur in this study at detention times of 60 days or less.

Summary

Due to the composition of the raw sludge, an infinite amount of time would be required to bring about a complete decomposition of the organic matter to CO_2 and H_2O. In sewage treatment practices currently employed, a more practical approach is taken; that is, the organic matter is allowed to decompose to a point where it will no longer be objectionable. The primary objective of this process is to produce a digested sludge which can be disposed of easily and safely. Thus, the prime criteria for digester operation is the organic content of the digested sludge. The volatile solids content is used as a measure. There are two objections which limit the use of this standard. It is not feasible to withdraw sludge daily, so that a current picture of the digestion process cannot be obtained.

The ideal characteristic of digested sludge would be one which not only will indicate the current condition but would also predict the condition in the near future. If such a characteristic could be found, remedial measures could be instituted before the onset of adverse conditions. Unfortunately, such an index of digestion is not available; rather, an evaluation must include all the mentioned characteristics.

Considering all the indexes graphically, the point where the slightest rate ceases and the greatest begins would be the most realistic operational detention time. The point of rate change was at the 30-day detention time level. Beyond this level, there is a marked change in all the chemical characteristics except gas production, which did not cease to decrease until the 17-day level.

Conclusions

This study indicated that after the "dynamic equilibrium" has been established, the following will occur:

1. At decreased loading levels, an increase in the following chemical indexes is expected; total volatile organic acids, 5-day BOD, relative quantity of settleable solids in the supernatant, relative quantities of butyric and propionic acids, relative quantities of carbon dioxide groups and hydrogen sulfide groups in the gas, and the relative amounts of volatile solids in the digested sludge.

2. At decreased loading levels, a decrease in the following occurs: pH, alkalinity, ammonia nitrogen, relative quantity of acetic acid in the supernatant, and rate of reduction of the volatile matter added.

3. Total gas production increased to the detention time where the total volatile organic acids were 2,000 mg/l as acetic acid.

4. A critical detention time, 30 days, existed from which an increase in length of detaining the solids had a negligible effect on digester efficiency.

However, a decrease in detention time will produce a marked decrease in efficiency.

5. At detention less than 30 days, operational difficulties will occur. The degree of the trouble will depend on the magnitude of reduction in the detention time.

Acknowledgment

This research was supported in part by research grant number RG 4822-C-1, USPHS Division of Research Grants and Fellowships, National Institutes of Health.

References

1. Mueller, L. E., Hindin, E., Lunsford, J. V., and Dunstan, G. H., "Some Characteristics of Anaerobic Sludge Digestion. I. Effect of Loading." *Sewage and Industrial Wastes*, **31**, 6, 669 (June 1959).
2. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes." 10th Ed., Amer. Pub. Health Assn., New York (1955).
3. Bulen, W. A., Varner, J. E., and Burrell, R. C., "Separation of Organic Acids from Plant Tissue." *Anal. Chem.*, **24**, 187 (1952).
4. Teletzke, G. H., "Determination of Organic Acids in Digesting Sludge by Partition Chromatography." Thesis, University of Wisconsin, Madison, Wis. (1955).
5. Mueller, H. F., Buswell, A. M., and Larson, T. E., "Chromatographic Determination of Volatile Acids." *Sewage and Industrial Wastes*, **28**, 3, 255 (Mar. 1956).
6. Buswell, A. M., "Important Considerations in Sludge Digestion. Part II.—Microbiology and Theory of Anaerobic Digestion." *Sewage Works Jour.*, **19**, 1, 28 (Jan. 1947).
7. Imhoff, K., and Fair, G. M., "Sewage Treatment." 2nd Ed., John Wiley & Sons, New York (1956).
8. Stadtman, T. C., and Barker, H., "Studies on the Methane Fermentation." *Arch. Biochem.*, **2**, 256 (1949).
9. Stadtman, F. C., and Barker, H., "Studies on Methane Fermentation." *Jour. Bacteriol.*, **61**, 1 (1951).
10. Stadtman, T. C., and Barker, H., "Studies on Methane Fermentation." *Jour. Bacteriol.*, **61**, 67 (1951).

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SEWAGE TREATMENT BY OXYGENATION THROUGH PERMEABLE PLASTIC FILMS

By R. B. Schaffer, F. J. Ludzack, and M. B. Ettinger

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Reports in the literature (1) (2) (3) (4) show that several plastic films have permeabilities which suggest that they might be useful to transfer oxygen to polluted water. However, the data given describe the permeability of dry films. A series of experiments was designed to evaluate the use of the more permeable plastic films for oxygenation of polluted water. Principal objectives were to evaluate (*a*) mechanical problems, (*b*) biological resistance of the film, (*c*) oxygen permeability, and (*d*) possibilities for practical use.

Four films were tested:

1. Visqueen, a polyethylene film, 1-mil thickness, Visking Corporation.
2. Conolex, a polyethylene film, 1-mil thickness, Continental Can Company.
3. Ethocel, an ethyl cellulose film, 3-mil thickness, Dow Chemical Company.
4. Trycite, an oriented polystyrene film, 1-mil thickness, Dow Chemical Company.

Apparatus

The apparatus used in this experiment (Figure 1) consisted of tanks fabricated from ⅛-in. Plexiglas with a combined baffle and oxygen transfer surface separating each tank into two compartments.

The baffle consisted of a ⅜-in. rubber gasket with a sheet of film on each side held in place by two aluminum frames bolted together. The frames were covered with aluminum screening to control stretching and to protect the film. Approximately 100 sq in. of plastic film surface on each side of the baffle was available to diffuse oxygen into the liquid substrate.

Tests

Commercial oxygen was introduced between the plastic surfaces at a pressure of 10 in. of water, which was adequate to overcome hydrostatic pressure and to maintain film separation. Later, a pressure of 12 in. of water was used but this did not give an observable increase in oxygen transfer. Average oxygen pressure was approximately one atmosphere after consideration of the opposing hydrostatic head. Higher pressures were not used because of greater incidence of rupture resulting from slight film imperfections or damage. Immersion of the plastic film in water reduced the oxygen transfer to 10 to 20 per cent of that of the dry film.

Eight liters of settled sewage (5-day BOD of 60 to 100 mg/l) were fed to the unit daily over a period of 12 to 18 hr.

Fluorescein dye added with the influent followed a broad front with a fair distribution pattern. The first dye reached the discharge point after influent addition, amounting to about ¼ of the tank volume.

Results

Manufacturer's data on oxygen permeability of Visqueen and Conolex were given as 550 and 445 cc/100 sq in./24 hr/atm, respectively. Oxygen transfer to the polluted water was approximately 75 cc/100 sq in./24 hr/

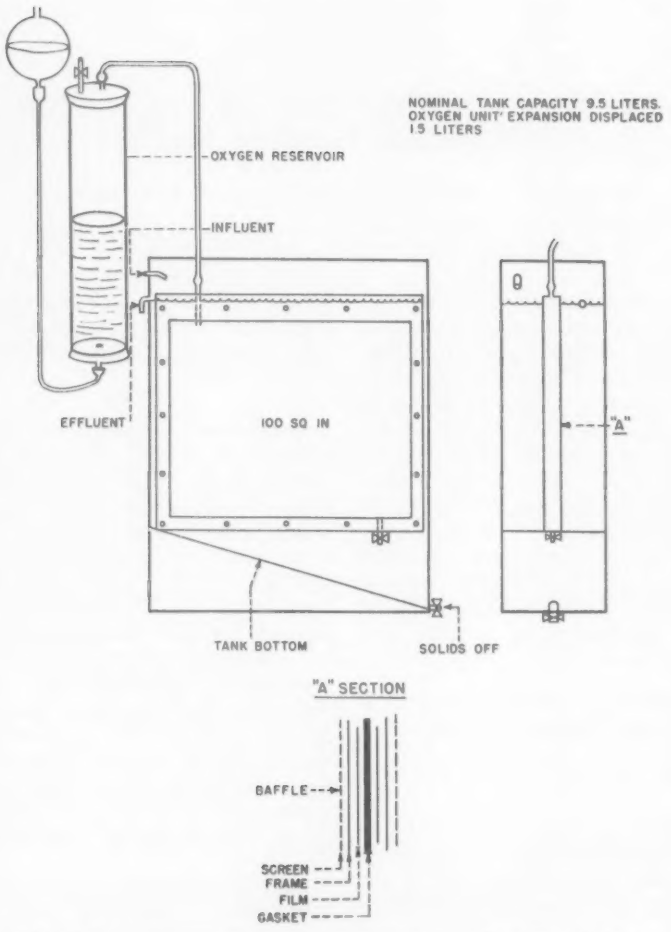

FIGURE 1.—Apparatus used for testing permeable plastic films for oxygenation of wastewater.

atm for each film in the experimental units. No permeability values were obtained from the manufacturer for Ethocel and Tryeite. The experimental values of 110 and 120 cc/100 sq in./24 hr/atm, respectively, showed oxygen permeabilities (gas to liquid) noticeably higher for these films.

To determine whether circulation of the substrate past the film surface would increase oxygen transfer, liquid was pumped at a rate of about one liter per minute from the discharge to the influent side with the flow primarily tangential to the film. There was no observable increase in oxygen transfer.

Dissolved oxygen, temperature, and pH were recorded daily. Significant amounts of DO were found only on Monday after the units had received no sewage feed for two days. The units were kept at room temperature (22 to 24°C) and the median pH was 7.2 with relatively little spread.

Chemical and biochemical oxygen

demand determinations were run periodically to estimate the treatment effectiveness of the units. The reduction of BOD was 50 to 85 per cent and COD reduction was 50 to 70 per cent.

Sediment in the unit was removed weekly. It rarely amounted to more than 1 g/week and had a volatile content of 30 to 45 per cent. It resembled sludge from benthol decomposition in physical and chemical characteristics.

Visible biological growth appeared on the influent side of the plastic film after four to six days of feeding. The growth on the feed side of one unit sloughed off almost completely and was spotty on other units. Growth on the film, in the discharge side, appeared in 7 to 10 days and maintained a uniform film coverage. The presence of growth on the film did not have an observable effect on oxygen transfer.

Microscopic observations of surface scum, film growth, and bottom sediment showed commonly encountered organisms. *Infusoria,* bacteria, and related growth appeared in the scum and near the water surface on the film. Near the bottom and in the sediment, bacteria, nematodes, and fewer protozoa were apparent. *Occilatoria* was the predominant algae.

With the effluent DO generally zero, a light was left on over the units to encourage growth of algae and subsequent oxygenation. Algae appeared to start several times but it was four to six weeks before they became prominent on the sides of the unit. Effluent DO remained unsatisfactory.

Checks of the oxygen content of the gas in the immersed film bag showed approximately 60-per cent oxygen after two weeks use. Remaining gas obviously was nitrogen entering from the liquid substrate. This oxygen dilution indicated frequent emptying of the bag was necessary to maintain oxygen partial pressure suitable for optimum transfer.

Summary and Conclusions

The permeable plastic films tested were delicate and required close control of pressure and protection from mechanical injury both before and after immersion. Oxygen transfer under test conditions also limited applicability. However, film degradation by biological action was not detectable after 60 days immersion.

The described oxygenation method may be useful where the limited transfer rates are of value. Bio-assay tests where maintenance of DO by aeration could change the substrate by sweeping out volatiles would be one possibility. DO could also be maintained in closed tanks for transportation of aquatic organisms by immersion of a suitable oxygen bag.

References

1. Brubaker, D. W., and Kammermeyer, K., "Separation of Gases by Plastic Membranes—Permeation Rates and Extent of Separation." *Ind. Eng. Chem.*, **46**, 733 (1954).
2. Brubaker, D. W., and Kammermeyer, K., "Flow of Gases Through Plastic Membranes." *Ind. Eng. Chem.*, **45**, 1145 (1953).
3. Brubaker, D. W., and Kammermeyer, K., "Separation of Gases by Means of Permeable Membranes—Permeability of Plastic Membranes to Gases." *Ind. Eng. Chem.*, **44**, 1465 (1952).
4. Stannett, V., and Szwarc, M., "The Permeability of Polymer Films to Gases—A Simple Relationship." *Jour. Polymer Sci.*, **16**, 89 (1955).

WATER POLLUTION CONTROL IS YOUR BUSINESS
SEE PAGE 1028

GAS CHROMATOGRAPHY FOR WASTE TREATMENT CONTROL *

By Werner N. Grune, Chun-fei Chueh, and Jack M. Hawkins

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In a research project designed to study the effect of radioactive materials on the sludge digestion process, it was desirable to compare the quality of the decomposed gas produced between the control and radioactively contaminated sludge. A daily analysis of the gas by conventional Orsat analyzer is slow and impractical due to the large quantity of sample gas consumed. This formed the basis for a project to develop the gas chromatographic method for sludge gas analysis.

Principle of Gas Chromatography

Chromatography, which was for the first time employed by Tswett (1) in 1906 to separate components of plant pigment, has long been used as a tool for analyzing liquid samples. Its adaptation to gas analysis has been developed during the last decade.

The principle of gas chromatography may be described briefly as follows. Consider a column which is packed with an adsorbent. A stream of sample gas mixture containing components A and B which are distributed uniformly in a non-adsorbing carrier gas C is passed through the column at a constant flow rate. Owing to the adsorptivity of the column packing, the molecules of component A will be temporarily retained by the adsorbent. During intimate contact between the gas stream and the adsorbent, component A will be distributed between stationary adsorbent and moving gas phase. At equilibrium a fraction of component A, X_A, is adsorbed in the stationary phase, which results in a probability equal to $1 - X_A$ for each single molecule of component A to stay in the gas phase and keep moving. As a result of a finite time interval, component A will move along with the carrier gas C only during a fraction, $1 - X_A$, of the total time. From identical reasoning, component B will move along with the carrier gas only during a fraction of time, $1 - X_B$. If X_A is smaller than X_B, component A will emerge from the column sooner than component B. Accordingly, A has been separated from B.

The time required for a particular gas traveling through a column is a function of the property of the gas at a specific temperature and flow rate. Therefore, the retention time can be used to identify the gas qualitatively.

A number of methods are available for the measurement of the individual gas components quantitatively, after separation from the original mixture. The newest of these methods is the ionization detection system, also claimed as the most sensitive method. Unfortunately, because of their high ionization potentials, hydrogen, nitrogen, oxygen, methane, carbon dioxide, and water vapor, which compose the major portion of sludge gas, are not detectable by an ionization detector

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

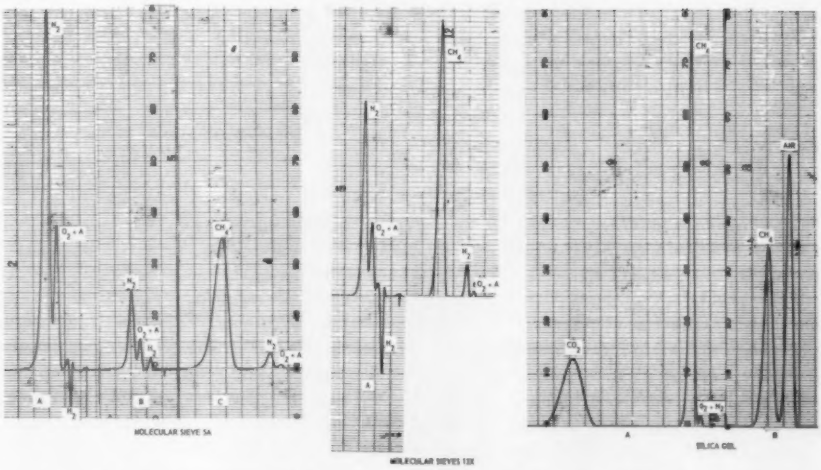

FIGURE 1.—Characteristic chromatograms obtained with adsorption columns.

(2). Simplicity of construction and operation, high sensitivity, and convenience of interpretation of data have made the conventional thermal conductivity cell the best choice for this particular type of gas mixture.

The thermal conductivity cell consists of a pair of matched and electrically-heated filaments, which form the two arms of a Wheatstone resistance bridge. One filament is surrounded by the unknown gas to be analyzed, and the other is in the reference, or carrier gas. The temperature difference between the filament and the surrounding metal block is, as a first approximation, inversely proportional to the conductivity of the gas. The filament may be either a carefully calibrated platinum wire or a thermistor bead. During operation, if the filaments of the cells are heated by equal current, exposed to gases of different conductivities, the resistance bridge will measure the degree of unbalance detectable with a millivolt meter or recorder. The deflection of the instrument will be proportional to the temperature difference and inversely proportional to the thermal conductivity difference between the gases, which in turn is a function of the concentration of sample present.

Adsorption versus Partition Separation

Gas-Solid Adsorption

It is generally believed that adsorption columns are more suitable for low boiling-point gases, such as methane and carbon dioxide, the major components of sludge gas. The initial work to find the best column was devoted to the various solid adsorbents, such as activated charcoal, silica gel, molecular sieves, silica alumina, and others. Both activated charcoal and silica gel separate air, methane and CO_2. Molecular sieves (both 5A and 13X) are able to separate hydrogen, oxygen, nitrogen, and methane. However, adsorption columns have a common deficiency—their strong adsorptivity to relatively high boiling-point vapors, especially for polar components. For example, carbon dioxide cannot pass through a molecular sieve column, because it is completely and permanently adsorbed. Carbon dioxide is able to pass through a short length of activated charcoal column, or through a relatively longer silica gel column.

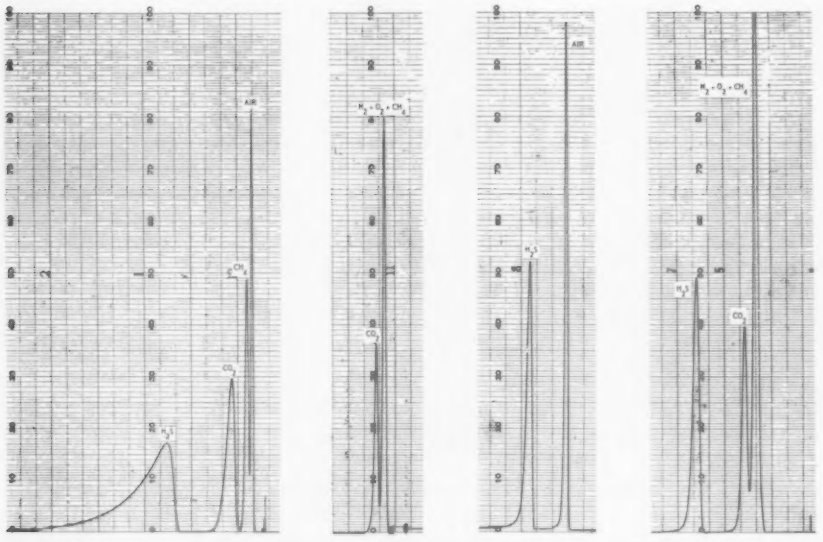

FIGURE 2.—Characteristic chromatograms obtained with gas liquid partition columns. First graph is from a 4¾-ft silicone grease column plus 3 in. of activated charcoal. Second and third are from 12-ft silicone grease columns. Last is from a 24-ft silicone grease column.

However, a very flat peak is produced which lowers the accuracy of interpretation. Hydrogen sulfide and NH_3 cannot pass through any of the adsorbents mentioned above.

Adsorption columns also adsorb water vapor irreversibly. After repeated injections of sludge gas samples, usually saturated with water vapor, the retention times of gases in the column are offset and consequently the resolving power of the column is reduced. Periodic regeneration by passing dry gas through the column, under elevated temperatures, is required to maintain the column in operating condition.

One example of use was a 12-ft silica gel column operating at 130°F. It was used for the routine analysis of 20, or more, daily samples for a period in excess of 6 months and maintained by periodic regeneration. An elevated column temperature will produce a sharper CO_2 peak; however, the degree of separation between air and methane will decrease. Figure 1 shows the results obtained from several types of adsorption columns with various gases.

Gas-Liquid Partition

As opposed to adsorption columns, gas-liquid partition columns are prepared by packing a tube with granules of a solid support material (such as firebrick), which has been coated with a layer of organic solvent. Generally speaking, a particle size between the limits of 28- to 48-mesh and a ratio of 40 to 100 of liquid to solid, by weight, is used. To select a suitable coating material, various organic solvents were studied, including silicone grease, tri-m-cresyl phosphate, di-n-butyl maleate, glycerine, dimethyl sulfolane, tri-iso-butylene, tetra-iso-butylene, silicone oil 550, and several others. Most of these are proficient in separating CO_2 and H_2S from air as well as from each other. However, air and CH_4, both of which are low

boiling-point, permanent type gases, will usually appear as a single peak. Successful separations are obtained only by using either silicone grease, silicone oil 550, or tetra-iso-butylene as the coating material in a column length of 60 to 80 ft.

These three gas-liquid partition columns produce sharp and symmetrical peaks for air, CH_4, CO_2, and H_2S. For the same volume of gas samples, air, CH_4, and CO_2 give almost identical peak heights. This means that without the need of a calibration curve the component percentages from peak height can be directly interpreted as volume percentages with less than five-per cent error, compared to a one-per cent accuracy obtained with a carefully constructed calibration curve. In many practical applications, the sacrifice of accuracy would be compensated by the expediency gained.

Figure 2 shows the results obtained from several silicone grease columns for the resolution of air, CH_4, CO_2, and H_2S. A 69-ft column of tetra-iso-butylene coated on C-22 firebrick produced the chromatograms shown in Figure 3 from routine sludge digestion gas analysis.

Gas-liquid partition columns are definitely less affected by the presence of water vapor in the sample than are adsorption columns. A 71-ft silicone grease column has been operated at 83°F for over 6 months with the daily injection of 20 samples, saturated with water vapor. No change in the retention time of CH_4 has occurred and less than a 15-per cent decrease in retention time of CO_2 has been noted.

Detection of Hydrogen Sulfide

Detection and analysis of H_2S present in sludge gas by the gas chromatographic technique presents a difficult problem unless the H_2S concentration is very high. As already pointed out, solid adsorption columns possess too strong an adsorptive power for a polar vapor, such as H_2S. Even gas-liquid partition columns adsorb H_2S irreversibly until they become saturated from the previous sample.

To determine which part of the column material, liquid coating or solid support material, is responsible for the permanent adsorption of H_2S, three columns were prepared by coating silicone oil 550 on firebrick with ratios of 25, 40, and 50 parts of liquid to 100 parts of solid, by weight, re-

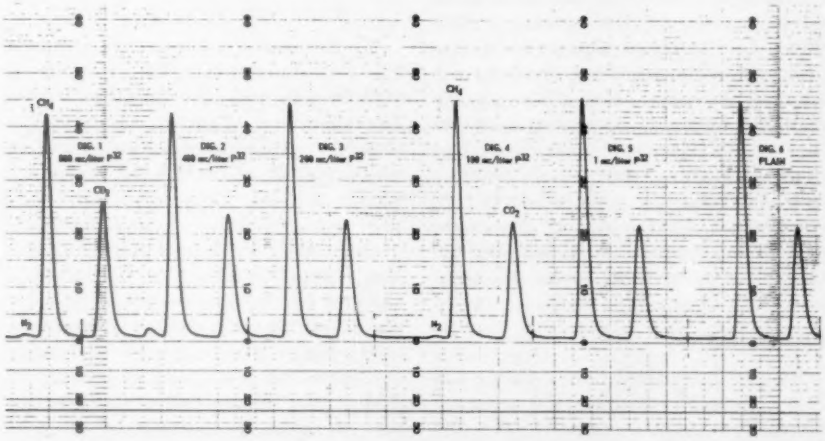

FIGURE 3.—Chromatogram produced from sludge digestion gas analysis in a 69-ft column of tetra-iso-butylene coated on firebrick.

spectively. It was noted that H_2S adsorption by the columns decreased with an increase in the liquid ratio in the column. This experimental result confirms the assumption that the H_2S is permanently adsorbed by the firebrick rather than by the coating liquid. Among the many methods investigated to reduce the adsorptivity of the firebrick—including the addition of small amounts (two per cent) of polar compounds, such as stearic acid, into the coating liquid—optimum results were obtained by pretreating firebrick with a dilute aqueous NaOH solution, followed by washing with distilled water until its pH value was near 7. Detection of as little as 100 ppm of H_2S in air has been achieved with columns prepared in this manner. It is believed that a similar technique may be applicable for the analysis of SO_2 from industrial flue gas due to the corresponding polarity between SO_2 and H_2S.

Effect of Temperature, Flow Rate, and Particle Size of Column Packing

Temperature

An increase in column operating temperature generally reduces the retention time, therefore reduces the resolving power of the column. This effect due to temperature rise is less pronounced in partition than in adsorption columns. For silica gel columns an optimum operating temperature of 130°F was chosen to reduce the time required for sample analysis and to increase the peak height of CO_2 resolution. In the use of gas-liquid partition columns, a relatively low temperature, such as room temperature, is favored.

Flow Rates

Except in extraordinary ranges of flow (below 30 or above 150 ml/min) where separation is generally poor, the flow rate exerts less effect on column efficiency than temperature. Since a higher flow rate decreases the retention time and thus the time for analysis, a higher flow rate is generally preferred, provided it will not dilute the sample so far as to reduce the sensitivity of the detection system. A flow rate of 70 to 100 ml/min has been found to be a practical range.

Particle Size

In a gas-liquid partition column, the liquid is coated on well-graded particles of solid support material (ground firebrick) produced from careful sieve analysis. The smaller the particle size, the larger the contact area that each particle provides. However, decreasing the size of the particle increases the pressure drop across the column (3). This factor is of particular concern since columns up to 70 ft are commonly used to separate air and methane. Experience here indicates that a gradation from 28 to 48 mesh represents a good compromise between the two limits. Repeated screening and wet sieving are required to remove the fines which can increase significantly the pressure drop, even when present only as a very small percentage of the solid support material.

Automatic Sampling Valve

To reduce the manual time required for the chromatographic analyses of various gas mixtures produced from 18 laboratory digesters, it was desirable to develop a sampling valve which could automatically introduce small samples (approximately 1-ml size) into the analyzer in definite sequence and on a continuous basis. The main difficulty with the development of the automatic sampling valve was to prevent the leakage of the relatively high-pressure stream of carrier gas into the low-pressure stream of sludge gas. Essentially, the problem was overcome by the use of O-rings, peripherally mounted between ports on a sliding shaft inside a circular

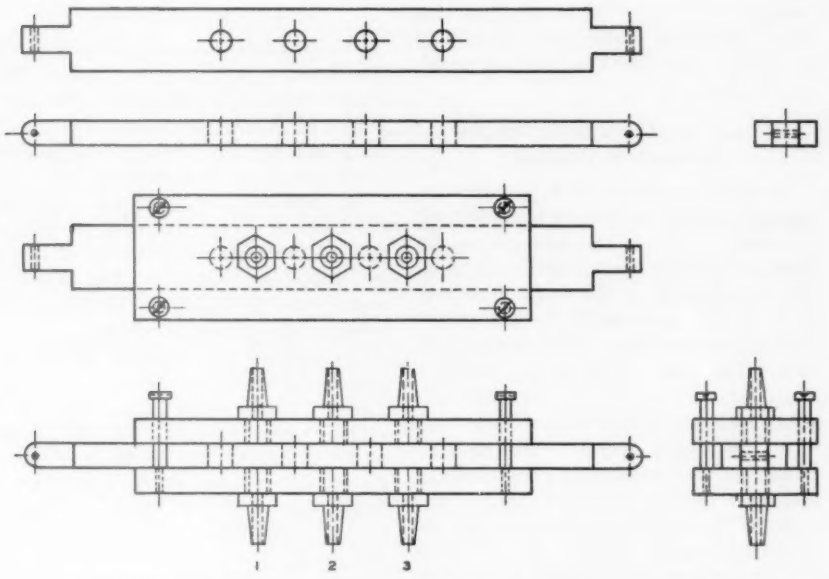

FIGURE 4.—Automatic gas sampling valve used in laboratory procedures.

housing. Figure 4 shows a sketch of the sampling valve with the carrier gas going through the center port and two sludge gas streams entering ports on either side. The circular plunger transports a slug of sample gas periodically from either of the sludge gas sampling streams to the center port, whence the carrier gas forces the sample of sludge gas into the analyzer.

Laboratory Research Application

The value of continuous, daily gas analyses for observing sludge digester operation and for the control of digestion was confirmed by routine gas analyses carried out by gas chromatographic techniques for the last three years on the effects of radioactive materials on anaerobic digestion. At the beginning of normal batch digestion, the sludge gas produced usually contains over 60 per cent CO_2, gradually drops down to 30 per cent CO_2 by the fifth day, and to 25 per cent by the 10th day. The digester will then maintain this level for the rest of the digestion period (50 to 90 days in this work) with a decrease of CO_2 content down to less than 20 per cent in some cases. Extraordinarily high concentrations of CO_2 usually indicate some difficulty with digester operation: (*a*) acid conditions developed in the medium, (*b*) toxic behavior due to the addition of chemicals, (*c*) a high intensity of radiation, or (*d*) poor anaerobic conditions (leakage of air into the digester). Whenever such air enters a digester this results in lowering the CH_4/CO_2 ratio.

A significant difference in sludge gas quality, as measured by the CO_2 concentration, in the presence of radioactive wastes, has frequently been found to exist even when all other parameters studied did not exhibit significant differences. The other parameters studied include: pH, electrolytic conductivity, oxidation-reduction potential, and volatile acids concentration. Consequently, the application of the gas chromatographic method is able to detect digester changes with

greater sensitivity than any of the aforementioned parameters which may be applied in the conventional treatment plant.

Other Applications in Waste Treatment Control

A specific application of gas chromatography plant operation and control, of special interest in areas where the sewage or waste treatment plant is in close proximity to the residential section of the community, is the detection and measurement of hydrogen sulfide. The chromatographic analyzer could be set for a maximum allowable concentration of H_2S in stack gas for, say, 1,000 ppm, which when reached would actuate a solenoid to activate a hydrogen sulfide scrubber.

Another possible application for gas chromatographic analysis is in monitoring for hydrogen sulfide to protect engine wear by mitigating corrosion if the sludge gas is used for engine fuel. It is known that when waste gas contains more than 0.25 to 1.0 per cent of hydrogen sulfide, it should be scrubbed to remove the hydrogen sulfide to protect the engine against corrosion (4)(5).

Some work on the separation and identification of complex mixtures of volatile sulfur-containing compounds has been done (6). Research has been conducted on the applications of the gas chromatographic technique for the analysis of complex mixtures of sulfur-containing compounds found in kraft pulp digester blow gas and black liquor combustion products. A column prepared from nonionic, surface-active Triton X-305 (an alkyl aryl polyether alcohol) has, thus far, produced the best separation of mixtures containing mercaptans, alkyl sulfides and disulfides, hydrogen sulfide, and sulfur dioxide. The high concentration of water vapor in the sample gas appears to be one of the most difficult problems. Results of field application and sensitivity range have not yet been reported.

Acknowledgments

This research has been supported by the National Institutes of Health, Research Grant RG-4945, since November 1956. Without the financial support from this agency these investigations could not have been carried out.

In addition, a National Science Foundation grant for the investigation of low-level radioisotope disposal by anaerobic digestion has directly contributed to this work both in manpower and equipment needs.

The authors are indebted for the assistance of a number of colleagues and students who were associated with various phases of this research. Much credit is due to Roy C. Peek, Graduate Research Assistant, and Bruce Bundsen, Marvin A. Turner, Jimmy G. Lee, and Robert J. Klett, Student Assistants.

The Barber-Colman Company, Wheelco-Instruments Division, provided a strip-chart recorder for most of the chromatographic gas analyses presented herein.

References

1. Tswett, M., *Ber. dtsch. botan. Ges.*, **24**, 384 (1906).
2. Baudean, J. E., Personal Communication, Perkin-Elmer Corp., Norwalk, Conn. (Apr. 1959).
3. Grune, W. N., Carter, J. V., and Keenan, J. P., "Development of a Continuous Gas Chromatographic Analyzer for Sludge Digestion Studies." *Sewage and Industrial Wastes*, **28**, 12, 1433 (Dec. 1956).
4. Stafford, R. W., "Iron Sponge as an Aid to Sewage Gas Engine Operation." *Sewage Works Eng.*, **13**, 343 (July 1942).
5. Norris, H. E., "Scrubbing Sewage Gas (Experiences with Dry and Wet Methods of Scrubbing at Peru, Indiana)." *Water Works and Sewerage*, **90**, 61 (Feb. 1943).
6. National Council for Stream Improvement, Inc., "Gas Chromatographic Analysis of Hydrogen Sulfide, Sulfur Dioxide, Mercaptans and Alkyl Sulfides and Disulfides." *Atmospheric Poll. Tech. Bull. No. 6* (April 13, 1959).

Industrial Wastes

FOOD–POPULATION EQUILIBRIA IN BENCH-SCALE BIO-OXIDATION UNITS *

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Within the last five years much attention has been directed toward the application of completely mixed biological oxidation systems to organic waste treatment. Concurrently, process terminology such as total oxidation and aerobic digestion has become popular. Somewhat unfortunately these two terms have come to connote panacean characteristics as a result of insufficient analytical data. However, within the past year some of the limitations of the so-called total oxidation application have been clarified (1) (2).

Purpose of Study

The present study was initiated early in 1958 with three primary objectives. The first was the detailed delineation of the limitations of the so-called total oxidation process by means of bench-scale units. The second objective was the demonstration of the hazard involved in direct or mathematical extrapolation of data obtained in batch experiments to the design of full-scale continuous bio-oxidation units. The third objective was a long-term program to demonstrate the anomaly of aerobic digestion in the destruction of biological solids. This paper pertains primarily to the first objective.

The entire investigation has been concerned only with soluble substrates since it is felt that dissolved organics present the most difficult problem in industrial waste treatment.

Theoretical Considerations

Although many organisms other than bacteria exist in activated sludge, the growth patterns are largely those of bacterial cultures through the sheer effect of numbers. Protozoans, rotifers, etc. are important to the over-all accomplishments of biological treatment but almost all of the suspended solids measured in the mixed liquor of biologically oxidized soluble substrates are bacteria. Therefore, the growth of an activated sludge may be considered as growth of bacteria and as conforming to certain laws. One law states that the size of a bacterial population after a certain time depends on three constants: (*a*) the growth lag, (*b*) the growth rate, and (*c*) the ultimate population that can be supported by the medium (3). This law formed the basis for the advocation of continuous total oxidation systems in which the population is envisioned as just in balance with the incoming substrate and consequently the only growth occurring is that needed to replace the dying older cells. However, this law

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

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is applicable only to once-fed batch systems or to continuous systems without culture recovery. In other words, the law does not apply to any biological system in which the organisms are retained and accumulated under conditions of continuous feeding. That this point is not widely understood is believed to be the reason that total oxidation systems without solids wastage have been so long and so extensively advocated. Theory thus does not uphold continuously fed total oxidation systems without solids wastage. In fact, theory presents still another reason why total oxidation systems may not be expected to work. This is the impossibility of indefinitely maintaining an uncontrolled growing culture with specific physiological characteristics. In other words, in total oxidation systems solids must settle if an acceptable effluent is to be produced. However, evolution in the form of mutation and selection is a necessary consequence of growth. Continued growth without wastage must inevitably bring changing characteristics. Settleability is obviously the critical property and a significant decrease in this characteristic results in a loss of culture. It should be noted that microbiologists utilize continuous culturing devices without solids recovery for the specific purpose of studying mutation rates (4). In total oxidation systems the effect of mutation and selection may be minimized by utilization of very low hydraulic surface loadings. Very low organic loadings are, of course, a natural result of the process and thus a very low growth rate is also characteristic.

Experimental Procedure

In 1955 Busch and Kalinske (5) presented the valid basis for the utilization of completely-mixed, continuously-fed, biological oxidation units in order to obtain optimum results in bio-oxidation. This paper stressed the importance of positive solids wastage control and absence of anaerobic settling conditions. Other workers have since utilized completely-mixed systems (6) (7). Total oxidation systems which have been installed are in essence completely-mixed systems without intentional solids wastage but utilizing separate sedimentation facilities in most cases.

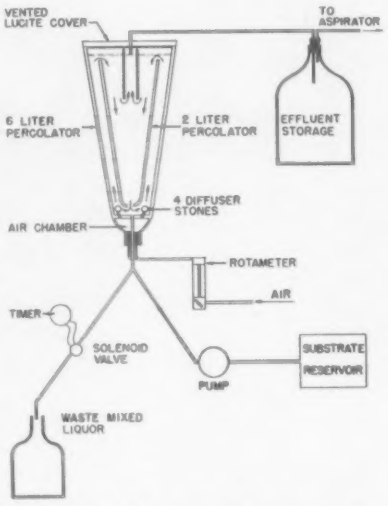

FIGURE 1.—Schematic diagram of bench-scale bio-oxidation unit.

For this study both batch and continuous completely-mixed, bench-scale bio-oxidation units were constructed. Each unit had a mixed liquor volume of 5.5 l. The continuous unit has been described in a recent publication (8) and is shown schematically in Figure 1. The timer-actuated wastage valve was not utilized in the present study.

The growth of bacteria in both once-fed batch- and continuously-fed continuous units without solids retention can be fully delineated by mathematical procedures. Garrett (9) has shown how these growth laws can be used to control the conventional activated sludge process for the treatment of sewage. A similar control over completely-mixed systems is possible through wastage of a fixed percentage of mixed liquor solids daily.

With mathematical formulation of these two cases well established, this study was restricted to a continued feeding batch system and a continuously-fed, completely mixed system designed for solids retention. No solids were intentionally wasted from either system although solids in the effluent of the continuous system were not recovered. The initial surface loading selected for the continuous unit was 1,440 gpd/sq ft. This relatively high loading was used to show the effect of culture changes in contrast with subsequent work at a surface loading of 150 gpd/sq ft, which is on the order of values reported for installed total oxidation systems.

The substrate used was glucose supplemented appropriately with nitrogen and phosphorus. To insure the presence of trace elements, tap water was used for the continuous unit solution. The batch unit was settled daily, two liters of supernatant withdrawn and the volume made up with tap water.

The air supply was metered in order that each unit would receive equal amounts of air.

This paper reports one year of operation. Feed rates were progressively increased from one to six grams of glucose per day. Whenever possible key analyses such as mixed-liquor solids were performed daily.

Experimental Results

Figure 2 shows mixed liquor solids data for the two systems. It is noted that the solids in the batch system continuously increased except for an accidental loss of one liter of mixed liquor on the 200th day.

The apparent day-to-day variation in the solids content of the batch unit during the latter portions of the study was undoubtedly due largely to the difficulty in obtaining a small representative sample. The solids became increasingly granular with large discrete particles present. However, in some instances the day-to-day variation shows a distinctive trend which seems highly coincidental. The most sig-

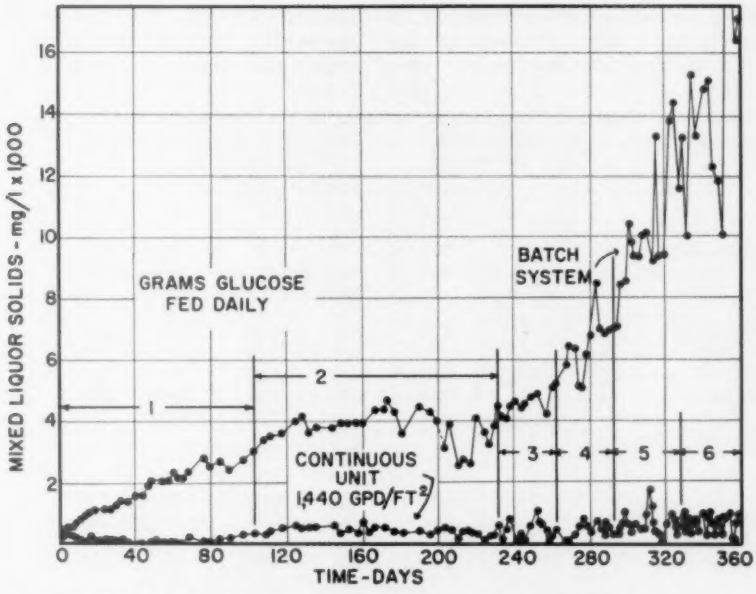

FIGURE 2.—Mixed liquor solids data for batch and continuous feed systems.

TABLE I.—Summary of Operating Data for Batch Unit

Determination	Glucose Fed Per Day (g)					
	1	2	3	4	5	6
Days of operation	103	128	31	30	34	32
MLSS at start (mg/l)	400	3,040	4,530	5,200	7,030	11,600
MLSS at end (mg/l)	3,040	4,320*	5,200	7,030	11,600	17,100
MLVSS at start (per cent)	90	85	80	80	80	80
MLVSS at end (per cent)	85	80	80	80	80	80
Supernat. SS-median (mg/l)	60	67	60	115	75	48
MLSS at start (g)	2.2	16.7	24.9	28.6	38.7	63.8
MLSS at end (g)	16.7	23.8	28.6	38.7	63.8	94.1
MLVSS at start (g)	2.0	14.2	19.9	22.9	31.0	51.0
MLVSS at end (g)	14.2	19.0	22.9	31.0	51.0	75.3
Supernat. SS-median (g)	0.12	0.13	0.12	0.23	0.15	0.10
SVI-median	30	20	15	10	10	10
Infl. BOD (g)	0.7	1.4	2.1	2.8	3.5	4.2
Supernat. BOD (mg/l)						
Filtered-median	—	—	3	3	5	3
Unfiltered-median	—	—	25	30	33	14
BOD loading (lb/lb MLVSS)						
Start	0.35	0.10	0.11	0.12	0.11	0.08
End	0.05	0.07	0.09	0.09	0.07	0.06
pH-median	8.4	8.4	8.2	8.1	8.0	8.0
ORP-median	250	200	240	240	240	210

* 74 days.

nificant observation to be made from the batch system data is that even after 103 days of operation at a fixed loading no food-population equilibrium was reached. BOD loadings (5-day, 20°C) during this time ranged from 0.35 to 0.05 lb/lb mixed liquor volatile suspended solids.

The extreme difference between solids content of the two systems is readily apparent. Particularly obvious in the higher loadings is the cyclic variation

TABLE II.—Summary of Operating Data for Continuous Unit *

Determination	Glucose Fed Per Day (g)					
	1	2	3	4	5	6
Days of operation	103	128	31	30	34	32
MLSS-median (mg/l)	104	446	450	563	625	508
MLVSS-median (per cent)	91	89	97	94	93	94
Effl. SS-median (mg/l)	17	43	53	63	68	92
MLSS-median (g)	0.57	2.45	2.48	3.10	3.44	2.79
MLVSS-median (g)	0.52	2.18	2.41	2.91	3.20	2.62
Effl. SS-median (g)	0.32	0.82	1.01	1.20	1.29	1.75
SVI-median	272	1425	925	1100	963	1250
Infl. BOD (mg/l)	39	78	117	156	195	234
Effl. BOD (mg/l)						
Filtered-median	—	—	3	6	6	3
Unfiltered-median	—	—	13	43	35	32
BOD loading (lb/lb MLVSS)	1.43	0.69	0.92	1.02	1.16	1.70
Sludge age (days)	1.8	3.0	2.5	2.6	2.7	1.6
pH-median	8.4	8.5	8.5	8.3	8.2	8.1
ORP-median	250	200	240	250	230	180

* Overflow rate, 1,440 gpd/sq ft; feed rate, 19 l/day.

TABLE III.—Summary of BOD Data (mg/l)

Unit	Sample	Median	Maximum	Standard Deviation
(a) 3 g Glucose Daily; $n = 11$				
Continuous	Filtered	3	9	3
Batch	Filtered	3	26	8
Continuous	Unfiltered	13	44	12
Batch	Unfiltered	25	30	12
(b) 4 g Glucose Daily; $n = 14$				
Continuous	Filtered	6	112	30
Batch	Filtered	3	24	5
Continuous	Unfiltered	43	112	29
Batch	Unfiltered	30	44	12
(c) 5 g Glucose Daily; $n = 19$				
Continuous	Filtered	6	141	117
Batch	Filtered	5	12	3
Continuous	Unfiltered	35	141	53
Batch	Unfiltered	33	58	14
(d) 6 g Glucose Daily $n = 13$				
Continuous	Filtered	3	8	4
Batch	Filtered	3	7	2
Continuous	Unfiltered	32	72	20
Batch	Unfiltered	14	20	5

in suspended solids of the continuous unit.

Table I contains a summary of the year's data for the batch system. Of some significance is the decrease in volatile content of the mixed liquor solids from an initial high of 90 per cent to a protracted minimum of 80 per cent. Sludge volume index data become of little significance in such a study with observed median values ranging from 30 to 10. The BOD data showed consistent results and median values are reported for each loading. ORP data are reported with reference to the calomel electrode.

Table II presents a summary of operational data for the continuous system. The high volatile content of the mixed liquor solids should especially be noted as well as the orderly increase in median effluent suspended solids values. The continuous system produced effluent BOD values of the same order of magnitude as those of the batch system. However, the continuous unit operated at median BOD loadings ranging from 4 to 30 times greater than batch unit loadings. Of perhaps equal significance is the greater variability of continuous unit BOD values, particularly the unfiltered samples (Table III). Although no particular statistical conclusions are warranted in view of low "n" values, standard deviations are reported as a measure of variability for want of a more significant parameter.

Mixed liquor solids data for the continuous system were subjected to statistical analysis and the results are shown in Figure 3. Note that the abscissa scale was split to prevent confusion in the drawing. As is shown in Figure 3, suspended solids for glucose loadings of 1 through 5 g/day demonstrated satisfactory normal arithmetic distribution characteristics; that is, the solids data approached a linear plot on arithmetic probability paper. At a loading of 6 g/day of glucose, however, the solids distribution approached geometric normality. Geometric normality is usually occasioned by a restrictive limit on one end of a series of observations. Since the low loading data showed arithmetic normality; i.e., zero not restricting, it may be speculated that at a loading of 6 g/day of glucose the rate of solids increase is sufficient to limit minimum solids concentrations and thus produce geometric normality.

Further evidence of different solids washout equilibria at the 6-g loading is shown in Figure 4. At loadings of 1 through 5 g/day of glucose, the median effluent solids represented essentially a constant proportion of the mixed liquor solids. The slope of the line of best fit indicates a 38-per cent loss by washout at a surface loading of 1,440 gpd/sq ft. As may be noted in Figure 2, the cyclic variation in solids content of the continuous unit at a loading of 6 g/day of glucose was more frequent and resulted in a lower median solids content than for the 4- or 5-g loading. This would be expected from a higher rate

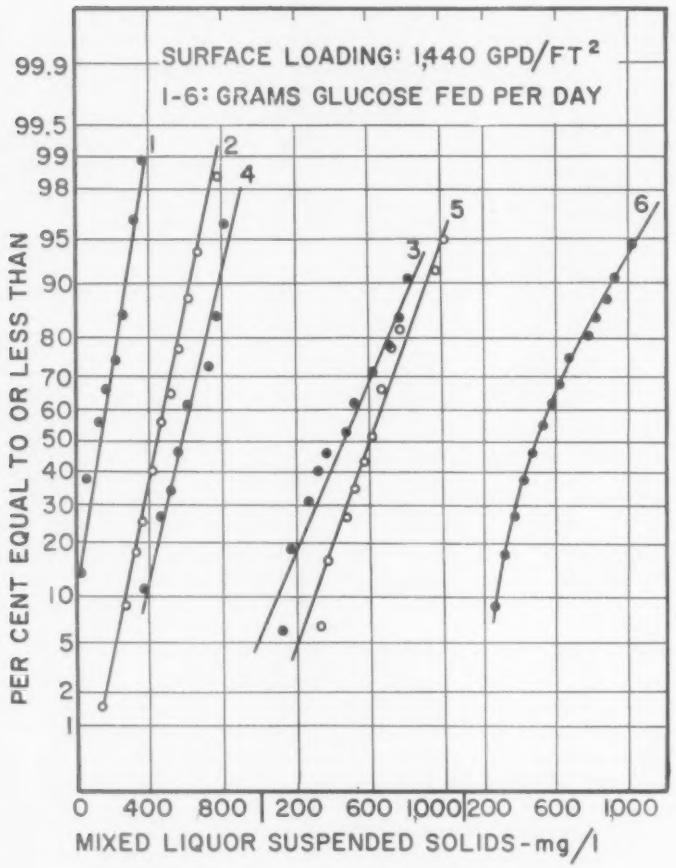

FIGURE 3.—Solids distribution for continuous unit.

of solids increase with the attendant susceptibility to mutation and selection. Thus, the opportunity for development and maintenance of a flocculent, rapidly settling sludge was limited.

Such speculation is supported by Figure 5 which shows a satisfactory correlation between median BOD loadings and median sludge age. Here, sludge age was calculated by dividing the median MLSS weight by the median effluent solids weight.

Figure 6 shows the progression of the SVI for the two systems. The difference in the sludge in the two systems is readily apparent and would seem to obviate direct mathematical forecast of the operation of a continuous unit of this type from batch data. It should be noted that for very low or very high solids concentrations the SVI loses any significance. For instance, a 10,000-mg/l concentration which settles not at all in a 1-l cylinder and a 100 mg/l concentration settling to 10 ml in 30 min both show an SVI of 100.

Of greater significance is the settling rate of the solids or the equivalent overflow rate or surface loading. Figure 7 shows the equivalent surface load-

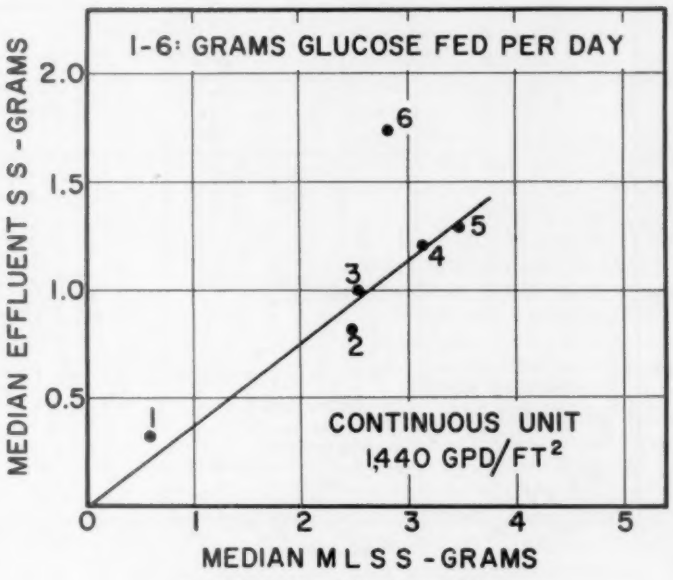

FIGURE 4.—Solids relationships.

ing for the settling characteristics of the solids in the continuous system at a loading of 6 g/day of glucose. The dotted lines indicate non-continuity of determinations. Clearly shown is the cyclic variation in settling characteristics when controlled wastage is not practiced. The solids settled at a rate equivalent to the existing surface loading of 1,440 gpd/sq ft only 26 per cent

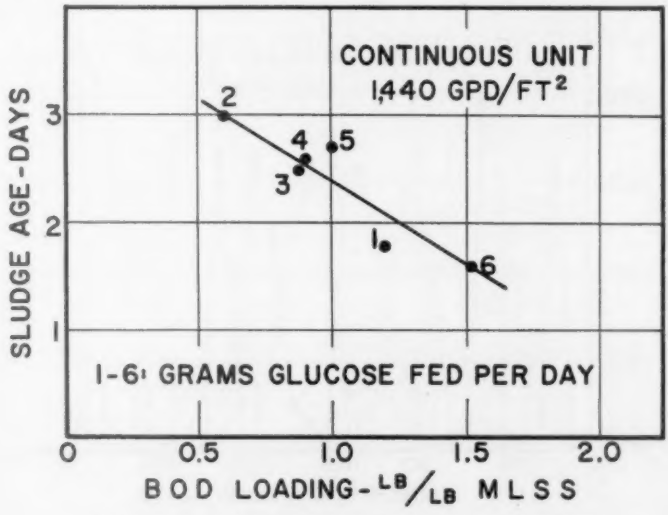

FIGURE 5.—BOD loading to sludge age relationships.

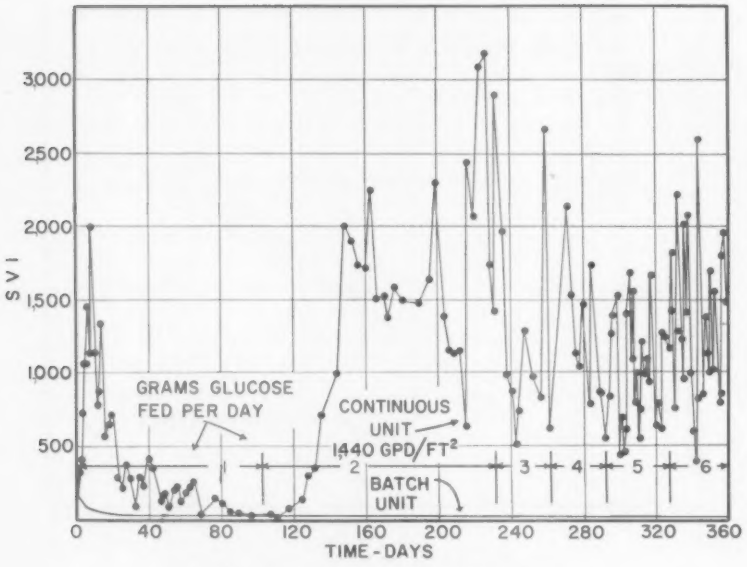

FIGURE 6.—Sludge volume index data.

of the time. The 50-per cent occurrence value was 150 gpd/sq ft and this value was selected for further study. As was noted previously the reported surface loadings of existing total oxidation systems are on the order of 150 gpd/sq ft.

Operation of the continuous unit for 33 days at a loading of 150 gpd/sq ft and a feed rate of 6 g/day of glucose

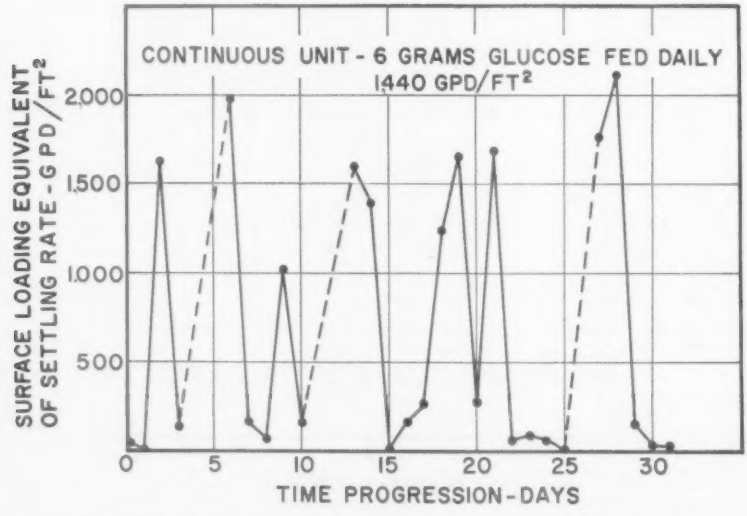

FIGURE 7.—Progression of variation in solids settling property.

TABLE IV.—Comparative Operating Data for Continuous Unit *

Performance Data	Surface Loading (gpd/sq ft)	
	150	1,440
Days of operation	33	32
MLSS-median (mg/l)	775	508
MLVSS-median (per cent)	97	94
Effl. SS-median (mg/l)	57	92
SVI-median	1,350	1,250
Infl. BOD (mg/l)	234	234
Effl. BOD (mg/l)		
Filtered-median	4	3
Unfiltered-median	20	32
BOD loading (lb/lb MLVSS)	1.08	1.70
Sludge age (days)	3.9	1.6
pH-median	8.1	8.1

* Feed rate, 6 g/day glucose.

yielded a median MLSS concentration of 775 mg/l. The median effluent suspended solids concentration was 57 mg/l. Table IV shows comparative data for the continuous unit at a 6-g/day glucose feed rate but a ten-fold difference in surface loading. It is noted that BOD removals are comparable but that the median sludge age increased from 1.6 to 3.9 days. Furthermore, although the SVI values are of the same order of magnitude, settling characteristics of the populations were markedly different. As previously noted, at a surface loading of 1,440 gpd/sq ft the solids settled at a rate equivalent to this loading only 26 per cent of the time and the 50-per cent occurrence settling rate was equivalent to a loading of 150 gpd/sq ft. When operating at 150 gpd/sq ft the solids settled at a rate equivalent to this loading only 16 per cent of the time and the 50-per cent occurrence settling rate was equivalent to a surface loading of 40 gpd/sq ft. This is shown in Figure 8. At least part of this discrepancy may be attributed to the longer cycle of solids variation due to the lower hydraulic loading. Figure 9 shows the progression of the solids cycles for the two loadings. It is felt that percentage data are not significant unless equivalent cycles are experienced. Current work is concerned with further evaluation of surface loading effects on systems of this type.

Discussion

These experimental data show the fallacy of total oxidation systems. Sy-

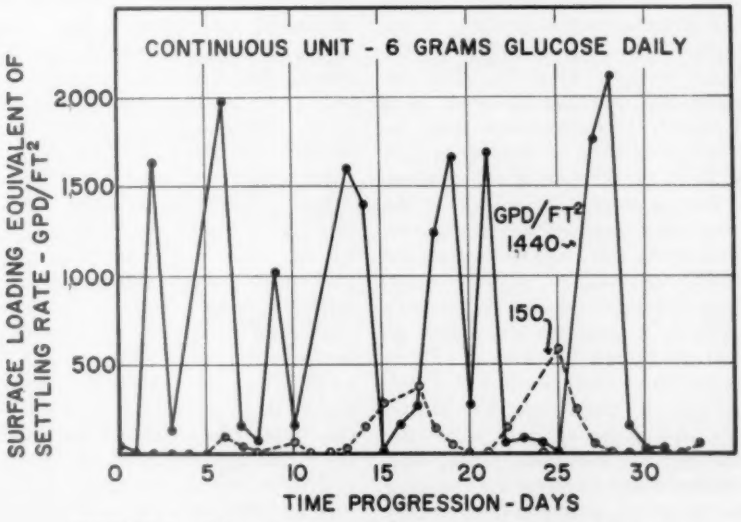

FIGURE 8.—Effect of surface loading on solids settling property.

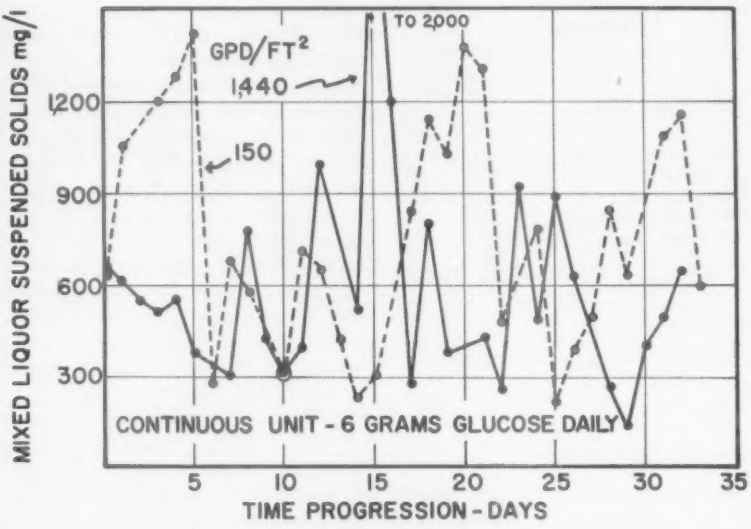

FIGURE 9.—Effect of surface loading on solids progression.

mons and McKinney (1) and Kountz and Forney (2) have also published data within the past year refuting earlier reports of successful total oxidation systems. There is no doubt that for certain small flow applications some form of aerobic treatment without intentional continuous sludge wastage may be practicable, particularly if appreciable dilution is available in the receiving stream. However, it is emphasized that the consideration of a total oxidation system for a large industrial installation is hazardous; for large cities the process is not applicable. Recent work has delineated the stepwise progression of aerobic decomposition (10) (11). The breakdown of organic compounds involves simultaneous oxidation and assimilation with the relative percentages dependent on the nature of the compound. There exists the theoretical possibility of encountering a waste which oxidizes readily and almost entirely with little production of bacterial protoplasm. For such a waste a process approaching a total oxidation system is theoretically feasible. However, for almost all industrial installations of any size, the concept of total oxidation is untenable.

The continuous unit was employed in this study as the first phase of a program to delineate the hazard of designing a continuous flow plant from batch experimental data. The prime deviation in design parameters is the nature of the biological solids grown under widely divergent hydraulic regimes. Batch studies eliminate the all-important settling requirement which is, of course, vital to a full-scale installation. That settling tests on batch-grown solids are insufficient to define permissible overflow rates for continuous flow systems is clearly shown by this study. The batch system solids became discrete and particulate and settled at rates equivalent to a surface loading of over 3,000 gpd/sq ft. The continuous system solids, on the other hand, remained extremely flocculent and settled very slowly, if at all. That this latter effect was not due solely to the initial high surface loading of 1,440 gpd/sq ft was demonstrated by operation at 150 gpd/sq ft and consequent production of solids settling at a rate

equivalent to this low surface loading only 16 per cent of the time during a 33-day period. Current work is underway to study the effects of controlled solids wastage in batch vs. continuous systems.

Summary

The results of one year's operation of continuous and batch biological oxidation systems utilizing a soluble substrate and no intentional solids wastage have been reported. Median values for soluble BOD in supernatant and effluent were consistently below 10 mg/l at BOD loadings ranging from 0.05 to 1.7 lb BOD per lb of volatile suspended solids. Suspended BOD values were a function of effluent suspended solids concentrations but no direct correlation was noted. Marked differences were noted in biological solids characteristics in the two systems. In neither environment was equilibrium reached between food and population even after as long as 103 days of operations at BOD loadings of 0.05 lb/lb VSS.

Conclusions

The following conclusions may be drawn from this study:

1. No food-population equilibrium was attained in either the batch or continuous system after operation at one organic substrate loading for as long as 103 days.

2. Biological solids in the continuous system showed cyclic fluctuations in concentration and settling characteristics.

3. Both batch and continuous systems consistently produced median effluent BOD values of less than 10 mg/l even though the continuous unit operated at loadings up to 30 times higher than the batch unit.

4. Total oxidation is neither theoretically nor practically attainable. Some buildup of biological solids is inevitable unless effluent carryover of solids is sufficient for balance.

5. For systems of the type studied, mathematical extrapolation of batch unit data to continuous plant design is not practicable.

References

1. Symons, J. M., and McKinney, R. E., "The Biochemistry of Nitrogen in the Synthesis of Activated Sludge." *Sewage and Industrial Wastes*, **30**, 7, 874 (July 1958).
2. Kountz, R. R., and Forney, C., Jr., "Metabolic Energy Balances in a Total Oxidation Activated Sludge System." *Sewage and Industrial Wastes*, **31**, 7, 819 (July 1959).
3. Monod, J., "The Growth of Bacterial Cultures." *Ann. Rev. Microbiol.*, (1949).
4. Novick, A., and Szilard, L., "Genetic Mechanisms in Bacteria and Bacterial Viruses, I." Cold Spring Harbor Symposia on Quantitative Biology, **16** (1951).
5. Busch, A. W., and Kalinske, A. A., "Utilization of the Kinetics of Activated Sludge in Process and Equipment Design." In "Biological Treatment of Sewage and Industrial Wastes," Vol. 1, p. 277, Reinhold Publishing Corp., New York (1956).
6. McKinney, R. E., Symons, J. M., Shifrin, W. G., and Venzn, M., "Design and Operation of a Complete Mixing Activated Sludge System." *Sewage and Industrial Wastes*, **30**, 3, 287 (Mar. 1958).
7. Tapleshay, J. A., "Total Oxidation Treatment of Organic Wastes." *Sewage and Industrial Wastes*, **30**, 5, 652 (May 1958).
8. Busch, A. W., "Theory and Design of Bench-Scale Units for Biological Oxidation Studies." *Water and Sewage Works*, **106**, 6, 254 (1959).
9. Garrett, M. T., Jr., "Hydraulic Control of Activated Sludge Growth Rate." *Sewage and Industrial Wastes*, **30**, 3, 253 (Mar. 1958).
10. Busch, A. W., "BOD Progression in Soluble Substrates." *Sewage and Industrial Wastes*, **30**, 11, 1336 (Nov. 1958).
11. Myrick, N., and Busch, A. W., "BOD Progression in Soluble Substrates. II. The Selective Stimulation of Respiration in Mixed Cultures of Bacteria and Protozoa." THIS JOURNAL, **32**, 7, 741 (July 1960).

PUBLIC RELATIONS AND INDUSTRIAL WASTES *

By Lloyd Stackhouse

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It is hoped that at the end of a technical meeting where wastes are discussed that a summing up could be written which would be clear to layman and technician alike.

A need for such a summary is demonstrated, for instance, in a newspaper report on such a conference. "Men with dust problems that can't be swept under a carpet met in Seattle yesterday to commiserate with industries suffering from odors that can't be washed away."

The story goes on to hit some highlights of what was said the previous day. The story contains neatly turned phrases, and, insofar as is known, is accurate—as far as it goes.

But to make the essence of this conference clear, it would seem desirable at the end to have another statement which might run along these lines:

Dateline Seattle, April 3—An optimistic picture of progress in the field of industrial waste disposal was painted in Seattle this week by a conference of technical experts. Consensus of their remarks indicates that Washington State, making remarkable strides in solving its problems of industrial waste, will undergo a 40-per cent increase in industrial plants during the next ten years . . . and so on.

It is a hopeful thing if, at the end of a meeting a conclusion can be reached. This is the ideal situation in public relations. It is the duty of the public relations release to say—in the simplest language possible—exactly what is happening, under what circumstances, and at what rate of speed.

But also, other facts of life must be faced. Too often, it is not possible to render a precise summing up. Too often, ideas and opinions cannot be evaluated with a slide rule. There is a real need for plain talk and the spirit of agreement, knowing that little may be agreed on at the end of a meeting. If there is lack of agreement or an inability to reduce thoughts to a 300-word press statement with which all will agree, the reason goes back to the basic bug that has not yet been ironed out of communications misunderstanding. It always has been present and will continue to be present in everything that is done. The role of the public relations program is to reduce this misunderstanding to the lowest degree practical.

Public Relations Factors

The purpose of this paper is to offer some information on the industrial waste picture and public relations. There is not so much concern as to what is in the picture of industrial waste—but the frame around it, or its size and shape in the public eye. There are three areas which will explain this.

1. The area of determinism. This involves motives, and how people act on them—the motives which are the driving force behind all public relations activities—the motives out of which grow the programs of utterance and action called public relations.

2. The area of word competition. This competition has grown fantasti-

* Presented at the Ninth Pacific Northwest Industrial Waste Conference; Seattle, Wash.; Apr. 2–3, 1959.

cally in recent years. Every waking instant there are the sounds of living things communicating with each other.

3. The area of compromise, the system which keeps people together in groups, societies, and conferences. Formal or otherwise, the force of compromise reduces, subdues, and subtly modifies the initial driving force. Compromise is the eye of the needle through which each public relations plan or project passes before it is put into effect.

Industry's Story

A public relations counselor believes in motives—selfish motives, sharply defined motives, motives which can be poked with a stick. It is unrealistic for a public relations program to attempt to mask the motives behind it. Every industry is, and should continue to be selfish. Why? Because the most enlightened form of selfishness in modern society is that which includes as a first priority item the matter of public interest and welfare. What is good for the public is good for most segments of it, including industry.

This is a safe generalization but the area of specifics is not. Recently there was proposed—although this was not for the first time—a three-part water management program. This was an industry-oriented program, but one which took into full account the equities of all water users. This program would perform the following three steps:

1. By areas, the present and future beneficial water uses of an area would be determined and enunciated. These uses most certainly would include the disposal of industrial wastes as a legitimate water use.

2. Water quality criteria would be established to protect these uses—criteria which would allow maximum use and reuse of the waters.

3. A program of monitoring to maintain required standards would be established and carried out.

This proposed program springs from a self-centered motive—the motive to survive. It is proposed by industry which is facing tremendous problems of industrial waste disposal. And because it is carefully thought out—because it preserves the equities of all concerned—because it is in the public interest—it is the type proposal which has tremendous public relations possibilities. It is the kind of program which can be sold.

This example is cited to underscore what is believed to be a basic truth in public relations as it relates to industrial waste. There has to be a healthy, selfish motive behind every proposal, or it will not succeed.

No one should ever be ashamed of selfish motives if they do not infringe on the rights and equities of others. Frankness should be used in setting forth the motives—and there is no more laudable motive extant than the one that every industry holds near to its heart—the motive of survival, which means staying in business, and showing a profit at the end of a year.

Lands are not re-forested because of some wet-eyed sentiment for the past—they are because of the economics of the future.

Water is not conserved for anything but a most selfish reason—it is needed for survival.

Millions of dollars in research and construction to solve the problems of industrial waste disposal are not spent just because industry is composed of nice people. It is done because of necessity.

Industry must stay in business. It must meet the demands of all customers for better products, lower cost products, rapidly produced products, newer products. That is industry's primary concern.

This is selfish. It is the way the world is. This is the area of determinism in public relations.

It becomes a frantic thing to work along lines that are unrealistic. It is

hard to write a press release that attributes altruistic virtues where they do not exist. It is quite impossible to make very many people believe such things.

Motives and Development

In any group discussing the industrial waste problem a variety of motives is represented. These may include education, industry, state government, federal government, food, forestry, etc. Each representative has a unique thing to say—an unusual way of thinking—and he is oriented to his own selfish motives. If there is hope for a brighter industrial waste picture in the future, ways must be discovered to bring these views together. Perhaps the news story does express it accurately. Did the delegates meet to commiserate, or to confer?

The three-step program mentioned earlier is a way to do that. It is, of course, not the only way. But it is a feasible program—a logical program. It is one with which a great many different kinds of water use activities can be accommodated.

To develop the steps in a program, an assumed assignment of setting up a public relations project is made. Motivation is provided by the healthy, selfish desire to achieve a design for industrial survival. Somehow, agreement is reached on the three-part water quality criteria program.

Now, the second important area of public relations called word competition is considered. Who is listening? What are they listening to? How is their attention captured?

Often the first temptation—and sometimes in public relations work this becomes almost a conditioned reflex—is to touch off a veritable snowstorm of press releases, so-called fact sheets, sample speeches, reports, and so on. This blizzard of trivia then descends upon the landscape, seeking a place to take hold.

Except for the high volume of paper consumption which such an activity promotes, it does little good.

It is simply a matter of volume. New masses of documents, produced in the mistaken belief of success in communicating, still are adding only a teacupful to the ocean of communications. The odds against getting people's attention are enormous.

There are 1,449 daily newspapers in the United States, including 23 in Washington State. The state also has 156 weekly newspapers. There are 43,117,180 television homes in this country, and 48,895,680 radio homes. No idea is offered here as to the number of press releases written each day—by industrial public relations departments, government publicity men, the press secretaries of trade associations, and so forth. Suffice it to say that many city editors have developed great skill in tossing this type of material into the waste basket as it comes along.

No one yet has calculated the public relations noise level in the United States—the intensity of the background noise of communications which is going on all the time. Assume that if total attention of everyone represented 100 on a scale, the day-to-day noise level might be 40. Forty must be reached with the message just to be noted. A much higher level is necessary to make a slight impression. To sell the program, still higher on the scale is a must. Of course, 100 is never reached. Even news of an event as catastrophic as the attack on Pearl Harbor isn't heard by everyone.

If the volume of material sent out does not do the job, what is the answer? There really is only one answer. The quality of the program—coupled with the energy and force of the motives behind it.

A valuable, workable idea—which is sharp around the edges—can capture the imagination and enthusiasm of people. In the public relations field

many highly qualified people are searching for such a plan.

Present and Future

The public relations aspects of industrial waste are not immediately promising. It appears that a program has not been offered that each not only will buy in his own mind, but will then go out and sell to others.

For a plan to grow out of a conference—where many motives are represented—the plan should become identified with and promoted by all of the parties concerned. It then would have some personality. It is suggested, therefore, that a plan could be developed for this area along the lines of the three-step program. However, it seems that at this moment this is some distance from being a reality.

First, the public has to truly understand some of the facts of life on industrial waste disposal. Everyone, in thinking about this problem, has to break the habit of looking back in anger. Perfect vision in the direction of yesterday does not help solve the problems of tomorrow. The danger that lies in looking back is emotion. It relates to that golden yesterday when all natural resources were untouched, and grandfather could harvest salmon from a river bank with a scoop shovel. As all are aware, there has been a decrease in the supply of fish. It seems that everyone is moving heaven and earth to solve the problems of declining salmon runs, and the many other resource problems as well.

But emotion about the past has preconditioned the public relations climate to the point that no matter how effectively and sincerely these problems are dealt with, some suspicion and resentment remain.

One of the most destructive things that can happen—in terms of destroying clear thinking and replacing it with emotion— is the initiative process. The initiative has been used, really mis-used, more than once in an attempt to get across to the voting public the technical problems which only the experts have a ghost of a chance of solving. In such campaigns, facts fall by the wayside and emotion takes over. Invariably the idea of returning to that golden yesterday becomes the theme.

Before the industrial waste picture can be clearly seen by enough people to do anything effective about it, the so-called public has to understand one thing. The public itself is responsible for the present situation. The problems are the result of the enormous pressure of population growth. No one advocates a reduction in size. Forecasts say that by 1975 growth will be 40, 50, or 75 per cent.

Again, this is because of a strong, healthy, selfish public motive. The motive is the desire for what is chosen to be called progress. So, by choice, backward looks in anger are out of order.

The third public relations factor which seems to affect this picture is compromise.

Within a gathering found at a technical meeting are found all the talent, background, desire, and healthy motives needed to produce a truly exciting and workable concept to solve industrial waste problems. Each, with his own ideas, must drive ahead as hard as he can, to that point in the negotiations where compromise must take place.

At that point it calls for cool heads, patience, and a most liberal supply of that sophisticated selfish motive mentioned earlier—the motive which has the public good as a first-priority item.

An optimistic viewpoint is that at the present time the situation as regards industrial wastes is at a point where an equitable, over-all plan can begin to develop.

DISPOSAL OF WASTES FROM THE PHOSPHATE INDUSTRY *

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Geologists estimate that the origin of the present phosphate formations dates back 10 or 15 million years when billions of minute particles were formed in seas somewhat similar to the present Gulf of Mexico. The sources of phosphorus were possibly sea-life excreta, remains of tiny phosphatic organisms, and inorganic precipitates from the sea water.

As the pellets formed, calcium carbonate was also precipitating and some quartz sand was being washed in from the shorelines. Thousands of species of sea life that utilized the calcium bicarbonate from the water to build their shells contributed to the formation of the limestone deposits. Many shark-like fish abounded and left their phosphatic teeth and bones. As the sediments accumulated slowly, their weight caused compaction and a very gradual sinking of the sea floor until a deposit of rock more than 200 ft thick was formed. Some of the strata were highly phosphatic; some were almost pure limestone; and some were almost all sand. The rock formation now known as the Hawthorn limestone developed during a probable interval of 10,000 years and covered most of Florida and parts of Alabama, Georgia, and South Carolina.

As sea levels lowered, the limestone which was exposed to the atmosphere underwent weathering and erosion. Much of the relatively easily leached limestone was removed through sinkholes and by streams. The less soluble phosphate and quartz sand were largely left behind. Then just before the last Glacial Age, the seas again inundated nearly all of Florida. As the shoreline moved inward with the flood and then outward as the waters receded, the quartz sand being carried down to the sea in the streams was smoothed out as the beaches continually changed, leaving a mantle of 10 to 20 ft of sand over much of the state.

Most of the "rotted" limestone and much of the phosphate were disintegrated by waves and then dissolved, except near the present shoreline where the process is continuing. Since that time, the sand-covered limestone has been "rotting" and dissolving as the rains drain through it and run on to the sea. Because bones and fine phosphates are not dissolved so readily, they remain with practically all of the quartz sand.

History of Phosphate Industry in Florida

Phosphate mining in Florida began in 1888 with the production of "river-pebble" phosphate on the Peace River near Arcadia. A year later, "land-pebble" phosphate was discovered near the "river-pebble" formation.

In the early days of mining by pick and shovel or by horse and scraper, the depth was limited by the water level. With the advent of dipper dredges, mining went on below water level, being limited by the capacity of the bucket and the length of its handle. The introduction of hydraulic mining, and later the electric dragline ex-

* Presented at the 1959 Annual Meeting, Florida Sewage and Industrial Wastes Assn.; Tampa, Fla.; Nov. 15–18, 1959.

cavator, permitted increases in the depth of mining and the amount of material that could be handled economically. Thus, the unit costs of production have been reduced. Marked progress in recovery of fine-grain phosphatic material began in 1927 through use of the flotation process.

Mining and Value of Phosphate

Phosphate rock mined in Florida in 1958 amounted to 10,851,000 long tons with a value of $69 million (1). The production given by the Bureau of Mines' Minerals Yearbook in 1957 is 10,191,000 long tons with a value of about $65 million. Of this output, 4,600,000 long tons were used to produce ordinary superphosphate, 1,800,000 long tons for triple superphosphate, and 700,000 long tons for elemental phosphorus.

Based on average per capita earnings of the 5,368 employees, the estimated annual payroll of the phosphate industry in Florida is about $24.5 million.

Mining of Rock Phosphate

In the land-pebble area, phosphate is found in the form of small grains and pebble rock embedded in a phosphate formation from 5 to 40 ft thick and 10 to 60 ft below the surface. The phosphate ore-bearing material known as "matrix" consists of approximately 30 to 60 per cent phosphate rock, 10 to 25 per cent quartz sand, and 15 to 40 per cent clay and colloidal phosphate, according to the nature of the field.

Draglines used in mining can move as much as 40,000 tons of overburden or phosphate deposit in a 24-hr working day (Figure 1). The overburden of clay, quartz sand, and low-grade phosphate is removed by draglines and deposited on a spoil-bank beside the cut. After removal of overburden, the dragline deposits the phosphate "matrix"

FIGURE 1.—Draglines used in mining phosphate rock.

FIGURE 2.—Phosphate washing and flotation plant.

at the side of the strip in a shallow pit, or well, whence the phosphate-rich material is sluiced into a sump by hydraulic monitors called "guns." The slurry formed during the sluicing operation is pumped to the phosphate concentrating plant where the clay and quartz sand are removed by washing, screening, and flotation processes.

Washing and Flotation Operations

At the washing and flotation plant, the slurry of water, phosphate, quartz sand, and clay passes through two processing stages, washing and flotation (Figure 2).

Phosphatic material is scrubbed, washed, and screened. The screening separates the material into two sizes, less than and larger than 1 mm. Material passing a 14-mesh screen comprises pebble rock which is more or less free from clay and quartz sand when delivered to loading bins for shipment. The smaller material is sent to feed storage areas for further processing in the flotation plant.

From the feed storage, the less-than-1-mm material is processed in sizers where the material ranging from 14 to 35 mesh is separated from that sized from 35 to 200 mesh.

Quartz sand is separated from the 14-to-35-mesh material either through agglomeration in spirals or on belt separators. The smaller, 35-to-200-mesh material is treated in flotation cells. Reagents used in floating the phosphate minerals are caustic soda, fuel oil, and a mixture of fatty and resins acids know as tall oil. Following the phosphate float, the material is treated in another flotation process where amines are used for the flotation of quartz sand not previously removed. This is sometimes called the "upside-down" float.

During the washing, sizing, and

flotation processes, clear water is introduced and wastewater is removed at several steps and routed to hydroseparators and/or settling areas in which the clay and sand settle, leaving clear water which is recycled.

Waste Disposal from Mining and Beneficiation Operations

Settling Areas

Settling areas are used as a means of waste disposal for the clay and quartz sand separated in the washing and flotation processes and also for the clarification of water to be reused either in the process or discharged into streams (Figure 3).

When phosphate mining begins in a new area, impounding dams are constructed to provide the necessary settling area to contain the clay and quartz sand. As mining progresses, the mined-out areas then are used as supplementary settling areas, the cuts being made in a manner such that water circulates through them, as in a settling area. The settling ponds within the dams cover areas up to 1,800 acres and frequently are divided into partitions, thus allowing the water to circulate slowly through the area.

The settling areas provide a means of waste disposal, but equally or perhaps more important, they provide clear water for reuse in the mining and process operations. Also, these areas act as a reservoir for the collection of rain water during the rainy season.

During the dry season, little, if any, water is wasted to the streams; only during the rainy season do filled settling areas release water. At some operations, an estimated maximum of 10 per cent of the total amount of water used is wasted to the streams as clear water from the settling areas.

Water Requirements of the Processes

Large quantities of water are needed in phosphate mining and reclamation —2,000 to 8,000 gpm at the mines and from 4,000 to 50,000 gpm at the re-

FIGURE 3.—Settling area used for disposal of clay and recovery of water for reuse.

covery plants, according to the size of the plant and its method of treatment. A small portion of the water is obtained from deep wells and in some cases a small quantity is pumped from streams; the major portion is obtained by the recirculation of the water that is reclaimed from the settling areas.

Water Treatment

The phosphate "slime" which is separated in the settling areas consists of a mixture of a colloid and a coarse suspension of one or more solids. From time to time the "slime" is difficult to settle because of its colloidal nature. At such times, the negative charge on the colloid may be neutralized by addition of a positive ion, specifically the calcium of calcium sulfate which promotes coagulation, agglomeration, and, subsequently, settling of the particles. Usually an addition of calcium sulfate is not necessary because it is present in the wastewater from the sand-flotation process. Electrolytes other than calcium sulfate may be used to promote settling of the slimes.

Waste Disposal

It has been shown (2) that the clear effluent from the phosphate mining and beneficiation operation is not deleterious to fish life. As in most industrial operations, emergencies and errors of personnel sometimes result in the discharge of water containing slime in suspension. Generally, the amount of slime discharged in these cases is not sufficient to cause appreciable damage to streams, although large quantities of slimes discharged as a consequence of a dam break may result in adverse effects (3). Recent studies (4) indicate that "with regard to elimination of radioactive substances" a highly turbid stream tends to be a decontaminative one, either through dispersals or as a result of deposition in the bottom mud. Hence, in the case of radioactive contamination of streams, it would be desirable to utilize some of the phosphate wastes as a decontaminant.

Waste Disposal from Chemical Manufacture

Superphosphate

Superphosphate is made by reacting equal parts of sulfuric acid and pulverized phosphate rock. The acid is usually one having a concentration between 50 and 56° Bé. The two materials are thoroughly mixed, usually in a batch operation; then the somewhat fluid mix is discharged to a "den" where it is allowed to harden or "set."

After the superphosphate has set, it is dug out of the den and transferred by means of elevators, car systems, or belt conveyors to a bay or bin where curing is completed.

The acid converts the relatively insoluble apatite $Ca_{10}F_2(PO_4)_6$ into mono-calcium phosphate, $Ca(H_2PO_4)_2 \cdot 2H_2O$, which is quickly available to the growing crop.

During acidulation and setting, carbon dioxide, silicon tetrafluoride (5), and water are evolved. The carbonates are decomposed by the acid, with evolution of CO_2, and about one-third of the fluorine in the rock is released as hydrofluorosilicic acid.

By the time the material has been elevated to the curing area by the conveyors, the solid superphosphate has cooled and there is little, if any, later liberation of fluorides.

Fluoride vapors are removed from the mixing vessel, the den, and the elevators under less than atmospheric pressure and passed through water sprays or suitable scrubbers. The scrubbing water containing the recovered fluorosilicic acid, and insoluble silicon hydroxide is recycled to bring the concentration of the acid to 18 to 25 per cent H_2SiF_6. It is necessary to use a multiple-step scrubber to re-

move all the fluorides from the gases and vapors.

The hydrated silica is removed from the acid by filtration and is washed with fresh water and then deposited in settling areas or dumps. The fluorosilicic acid is sold as a liquid or it may be converted to other compounds, usually the sodium salt.

To prepare the sodium salt, the acid is mixed, while being stirred, with 1½ to 2 times the theoretical quantity of sodium chloride in solution. The sodium fluorosilicate precipitates in a white, gelatinous-appearing but crystalline form. It is washed with water, centrifuged, dried, and pulverized. The induced hydrochloric acid waste may be impounded or neutralized with either ground limestone, ground olivine, or hydrated lime. Other fluorosilicates may be made in a similar manner.

Triple Superphosphate

Triple superphosphate, also known as double, treble, multiple, or concentrated superphosphate, is made by acidulating phosphate rock with phosphoric acid instead of sulfuric acid. The following equation is usually given as representing the resultant chemical reactions:

$$3\,Ca_{10}F_2(PO_4)_6 + 42\,H_3PO_4 + 28\,H_2O + SiO_2 \rightarrow 30\,Ca(H_2PO_4)_2 \cdot H_2O + H_2SiF_6$$

fluorapatite (phosphate rock); phosphoric acid; water; silica; monohydrated calcium phosphate; hydrofluorosilicic acid

Phosphoric acid used in the manufacture of the triple superphosphate is obtained by leaching phosphate rock with either the "wet-process" or the "electric-furnace" acid. The resulting calcium sulfate and other insoluble materials are filtered from the engendered phosphoric acid in the slurry, generally in a vacuum-type filter. The sulfate cake is washed to remove the phosphoric acid which also contains some fluorosilicic acid.

Acid fluorides are evolved during the reaction between the phosphate rock and the sulfuric acid and are recovered as hydrofluorosilicic acid through scrubbing (Figures 4 and 5). The dilute phosphoric acid is concentrated in multiple effect evaporators, and fluorides released during the evaporation are recovered in electrostatic separators or by scrubbing, as in the manner described for the manufacture of superphosphate.

The calcium sulfate cake is transferred into settling areas where the solid material is retained. Clear water from the settling areas which contains dissolved calcium sulfate, dilute phosphoric acid, and some fluorosilicic acid is either recycled for use in the plant or treated in a two-step process to remove the soluble fluorides. The first treatment utilizes either ground limestone or a lime slurry, followed by settling. The clear water from the first treatment then is treated with lime slurry and allowed to settle in a separate area. Water from plant washing and from the evaporators may be added to the waters sent to the calcium sulfate settling area.

Water entering the first treatment step may contain about 1,700 mg/l F and 5,000 mg/l P_2O_5; it is treated with ground limestone or lime slurry to a pH of 3.2 to 3.8. The fluoride content is reduced to approximately 50 mg/l F, but the P_2O_5 content is reduced little, if any. Insoluble fluorides of calcium are removed by settling,

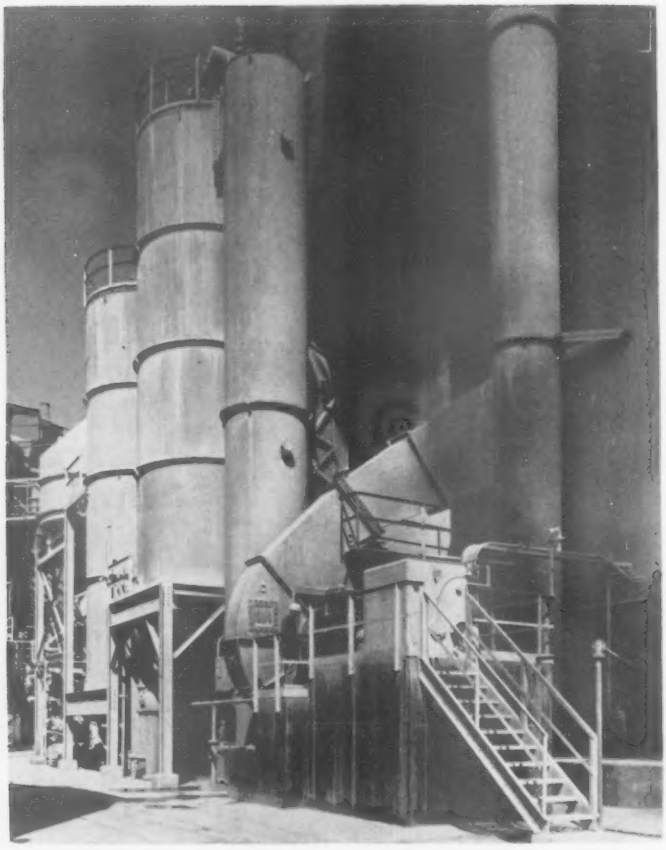

FIGURE 4.—Scrubbers used for removal of fluorides from triple superphosphate manufacturing.

and the clear liquid is either pumped or allowed to flow by gravity into another collection area where lime slurry is added to bring the solution to pH 7.0. The resultant precipitate then is removed by settling, and the clear water, which contains practically no P_2O_5 and from 3 to 5 mg/l F, is either returned to the plant for reuse or wasted into streams.

It has been found that the two-step treatment is necessary to reduce the fluoride content of the water below 25 mg/l F. When the ratio of P_2O_5 to F is equal to or greater than 11:1, as is the case with the water from the first treating step, the fluorides will be separated probably as apatite or other compounds, and the soluble fluorides will be diminished to the lower value of 5 mg/l F. Single-step treatment to pH 7.0 will reduce the fluoride content of the water only to 25 to 40 mg/l F.

According to Waggaman (6), a typical manufacturing procedure for making the triple superphosphate is as follows:

Finely ground rock (32 per cent P_2O_5) is treated with phosphoric acid (50.7 per cent H_3PO_4). The acid

(at a temperature of 140°F) and the rock (80 per cent passing a 200-mesh screen) are weighed in batches of 2,800 to 1,500 pounds, respectively, and added simultaneously to the pan of a 2-ton Stedman-type mixer. After thorough stirring for three minutes, the slurry is discharged directly to a bin or a wide conveyor belt which carries the material to an open reaction chamber where it solidifies. After several hours, it is moved by grab bucket or otherwise to another bin where it is allowed to cure for about three weeks, after which it is taken to a drier which reduces the moisture some 3 to 5 per cent. The product then is cooled, crushed, screened, and stored for shipment.

When the phosphoric acid contains 68 to 75 per cent H_3PO_4, the ensuing triple superphosphate does not have to be dried. With the use of the concentrated acid, the resultant slurry solidifies within 30 sec into a tough, plastic mass which can be transferred by means of belt conveyors directly to the curing pile.

A continuous process for the manufacture of triple superphosphate has been developed by the Tennessee Valley Authority (7). In this process, ground phosphate rock is fed through a constant-weight feeder into a specially designed cone into which 70- to 80-per cent phosphoric acid is pumped tangentially. Mixing in the cone is done in 2 sec and the slurry then is discharged to a belt conveyor.

During the reaction in the mixer, fluorides are evolved and can be blown along with the other vapors to the scrubbing system; fluorides also are evolved during the time the hot slurry

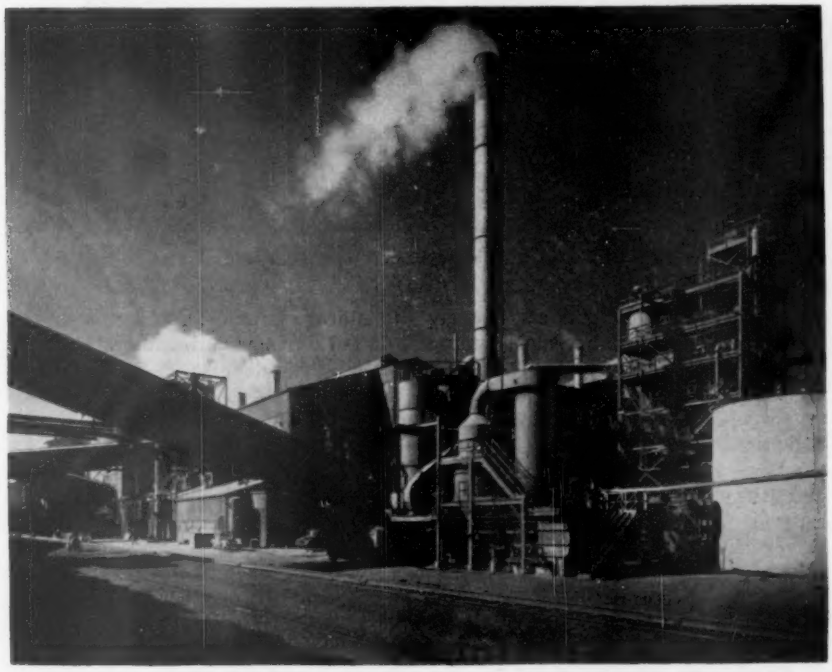

FIGURE 5.—Fluorosilicic acid is a by-product of this plant's effluent control procedures. Recovery equipment is located at the base of the tall stack. Purification is accomplished by filtration. Tank at right holds purified acid.

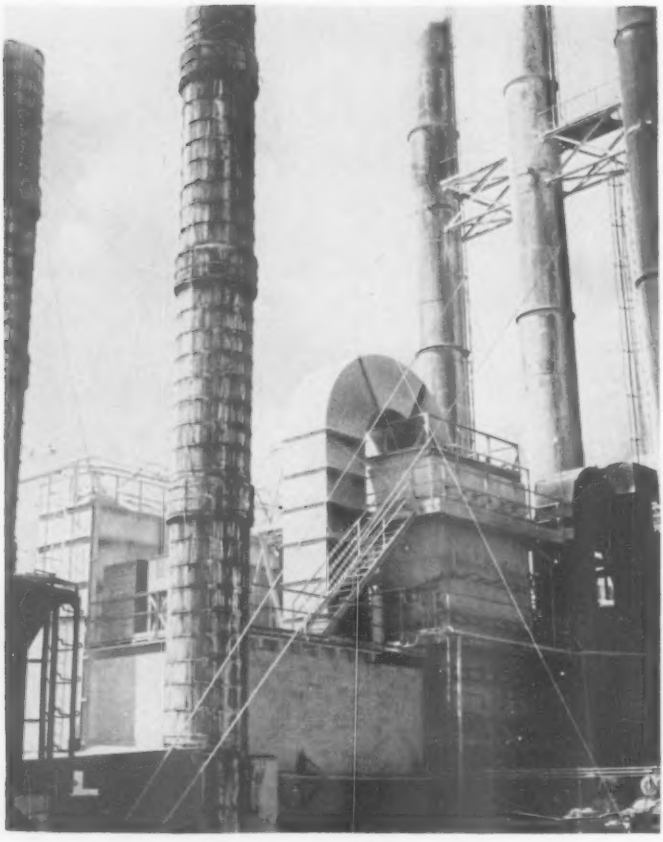

FIGURE 6.—Scrubbing system for removal of fluorides.

is being transferred and also during the curing. They are removed from the transfer systems under less than atmospheric pressure and the vapors are pumped to the scrubbing system.

Because of the large curing area, the large volume of air in these areas, and the low concentration of the emitted fluoride vapors, no satisfactory economical method has been developed for the collection of the fluorides evolved during the curing. Recently it has been found that there will be little or no further evolution of fluoride vapors in curing if the triple superphosphate is disintegrated and cooled before being transferred to storage areas. Cooling is accomplished during the disintegration process which is done in an enclosed area, and the fluoride vapors are removed and pumped to the scrubbing system.

In the processes where the triple superphosphate is to be granulated or nodulized, the material is transferred directly from the reaction mixer to a rotary dryer. The fluorides in the gases from the dryer are scrubbed with water in the same manner as in the other operations.

Defluorinated Phosphate

Defluorinated phosphate is made by heating phosphate rock in an atmos-

phere of steam in a rotary calciner at temperatures of 2,400 to 2,800°F or through fusion in a vertical furnace. In the absence of silica, fluorides are evolved as hydrofluoric acid (8)(9).

One method of recovery of fluorides consists of absorption in a tower of lump limestone at temperatures above the dew point of the stack gas. The reaction product separates from the limestone lumps in the form of fines. Portions of the bed are withdrawn from the tower at intervals, screened to remove the fines, and the oversize is recycled to the tower together with fresh makeup limestone.

A recent method for the recovery of fluorides consists of passing the gases through a series of water sprays located in three separate spray chambers (Figure 6). In the first chamber, the acid water is recycled through the sprays and is used primarily as a cooling chamber for the hot exit gases of the furnace. In the second chamber the acidic water is recycled to bring its concentration to approximately 5 per cent equivalence of hydrofluoric acid. Acid is withdrawn and fresh water is added to the system to maintain the effluent acid at the desired concentration. Scrubbing in the third chamber is supplemented by the addition of finely ground limestone which is blown into the chamber with the entering gases from the exit of the second chamber.

Acid from the spray chambers is collected and processed to produce alkaline fluorides. In some cases, by-product hydrochloric acid is formed and this is neutralized with caustic soda and lime slurry before being transferred to settling areas. When necessary, effluent from the settling areas is treated with lime slurry to bring the water to pH 7.0.

Elemental Phosphorus

Elemental phosphorus is produced in the electric furnace under reducing conditions by the volatilization of the element from its compounds. The following reaction is considered to take place, the raw materials being phosphate rock, quartz, and coke:

$$Ca_{10}F_2(PO_4)_6 + 9\ SiO_2 + 15\ C \rightarrow CaF_2 + 9\ CaO{\cdot}SiO_2 + 6\ P + 15\ CO$$

The molten calcium silicofluoride is tapped from the furnace periodically and is made into either "ballast" or expanded slag. When the phosphate rock has a low content of argillaceous material, the quench contains P_2O_5 and is a good liming material.

The vapors of elemental phosphorus pass from the furnace along with the carbon monoxide and some fluorides into a series of air-cooled condensers where elemental phosphorus condenses as a liquid that is collected under water. The gases and remaining vapor pass from the condensers through multiple-unit water sprays and thence through water-sealed pumps to an effluent stack. The gases, mostly carbon monoxide, are either burned in the raw-material dryers or at the exit of the stack.

Fluorides carried over with the phosphorus vapor from the furnace are caught either in the water under the condensers, in the spray units, or in the pump circulating water. These fluorides along with the small amount of oxidized phosphorus are delivered to a settling area. The clear water from the settling area is treated with a lime slurry to bring it to pH 7.0 and to precipitate the fluorides and phosphates. These precipitates are collected in a separate settling area, the clear effluent either being recycled for plant use or allowed to overflow to waste.

In some operations the phosphate charge to the furnace is sintered or nodulized. During this operation, hydrofluoric acid is evolved and is recovered in the same manner as in the defluorinated-phosphate process. When the nodules are from washed "sands," and, hence, have a low con-

TABLE I.—Waste Control Expenditures by Nine Companies in Florida

Item	Pollution Control Costs (millions of dollars)		
	Water	Air	Total
Research, development, installation	4.6	6.7	11.3
Annual operation	1.6	1.0	2.6
Control equipment ordered or being installed	0.2	1.0	1.2

tent of silica, about 90 per cent of the evolved fluoric gases is in the form of hydrogen fluoride.

Water and Air Pollution Control Expenditures

During November 1959, the Florida Phosphate Council determined the expenditures made for waste control measures by nine companies operating in the Polk-East Hillsborough County area. These costs are listed in Table I.

Acknowledgment

The author wishes to acknowledge the assistance received from his many friends in the industry who supplied much of the information on the chemical manufacturing processes and treatment of their wastes. Figures 1, 2, and 3 are by courtesy of The American Agricultural Chemical Company; Figures 4 and 5, International Mining and Chemical Company; and, Figure 6, Smith-Douglass Co., Inc.

References

1. Shirley, L. E., "The Mineral Industry of Florida." Advance summary, Mineral Industry Surveys, U. S. Bureau of Mines (July 28, 1959).
2. Specht, R. C., "Phosphate Waste Studies." Fla. Eng. and Ind. Exp. Sta., Bull. Ser. No. 32 (Feb. 1950).
3. Lanquist, E., "Peace and Alafia River Stream Sanitation Studies." Suppl. II to Vol. II, Fla. State Bd. of Health (June 1955).
4. Lackey, J. B., Morgan, G. B., and Hart, O. H., "Turbidity Effects in Natural Waters in Relation to Organisms and Uptake of Radioisotopes." Fla. Eng. and Ind. Exp. Sta., Tech. Paper No. 167 (Aug. 1959).
5. Semrau, K. T., "Emissions of Fluorides from Industrial Processes." *Jour. Air Pollution Control Assn.*, **7**, 2, 92 (Aug. 1957).
6. Waggaman, W. H., "Phosphoric Acid, Phosphates and Phosphatic Fertilizers." 2nd Ed., ACS Monograph Ser. No. 34, Reinhold Publishing Corp. (1953).
7. Bridge, G. L., "Development of Processes for Production of Concentrated Superphosphate." TVA Chem. Engr. Rep. No. 5 (1949).
8. Hignet, T. P., and Seigel, M. P., "Fluorine Recovery from Stack Gases." *Ind. Eng. Chem.*, **41**, 2493 (1949).
9. MacIntire, W. H., Hardin, L. J., and Hester, W., "Measurement of Atmospheric Fluorine—Analyses of Rainwater and Spanish Moss Exposures." *Ind. Eng. Chem.*, **44**, 1365 (1952).

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CONTROL OF METAL FINISHING WASTES USING ORP *

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The design and operation of metal finishing wastes treatment plants are problems of real interest to a large cross-section of industry, and the aircraft industry in particular is concerned with wastes of this type.

The construction of the advanced models of military aircraft requires a large number of process methods, and the industrial wastes from a plant producing these aircraft may contain almost every type of contamination to some extent.

When the manufacturing methods were developed for the B47 and B52 bombers, it was found that the waste effluents from such a facility as the Wichita plant included not only metal finishing wastes, but many others as well. These included plastics wastes, large quantities of stable oil emulsions, coolants, jet engine fuel residues, detergents, paint residues, phenolic dyes, and test solutions from special operations.

Boeing Waste Treatment Plant

The industrial waste treatment plant at the Boeing-Wichita facilities was completed in 1957. Such a treatment plant provides an excellent opportunity to investigate the available methods of control being used in the various treatment processes. Management has been aware of the company's responsibilities in the field of pollution control, and has encouraged study of modern processes and methods of control in industrial waste treatment. A study of the use of ORP in the control of ozone oxidation of cyanides for this plant has been reported (1). This present work deals with the ORP control of the chromate reduction process.

The Boeing industrial waste treatment plant consists of a two-step operation: (*a*) the wastes are reduced and precipitated, and (*b*) then oxidized. The reduction reaction is carried out at a pH of 2.5 using sulfur dioxide as a reductant, and the oxidation process is carried out at a pH of 8 using both ozone and biological oxidation. The chromate reduction process has been widely used and recommended as the most generally applicable chromate removal process for metal finishing wastes (2).

Schematically, the treatment process is shown in Figure 1 and the pH control system is shown in Figure 2. The treatment may be described as follows: 4 to 5 mil gal of waste a week representing about half of the total water usage at Boeing, flows to the treatment plant through two segregated industrial sewers. The waste flows into grit and oil separator pits, then overflows into segregated 110,000-gal holding tanks. The waste is charged into a stirred reaction tank where the pH is lowered to 2.5 automatically with sulfuric acid, and ferrous sulfate and sulfur dioxide (gas) are added. The sulfur dioxide feed rate is automatically adjusted using ORP control. The treated waste flows

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

to a solids-contact basin where the pH is automatically maintained at 7.4 using recirculated lime slurry. Caustic soda, alum, bentonite, coagulant aids, and ferrous sulfate can be added at this point, and the precipitated chromium hydroxide settled out. The waste then flows to a 100,000-gal surge tank. At this point a separate stream of alkaline chrome-free waste flows into the plant from a grit and oil separator. The mixture of wastes is recarbonated by submerged combustion, and pumped at a pH of approximately 8 to an ozone absorption tower. Caustic soda or soda ash can be added in the tower sump to raise the pH to 8. 360 lb/day of ozone are available to reduce an average chemical oxygen demand of 30 mg/l to close to zero. The pH is raised to 8.5 with lime slurry in a solids-contact basin. Again caustic soda, bentonite, alum, coagulant aids, and ferrous sulfate can be added, if desired. The waste then flows to another recarbonator, and the pH reduced to 7.5, from whence it overflows into a third solids-contact basin. The

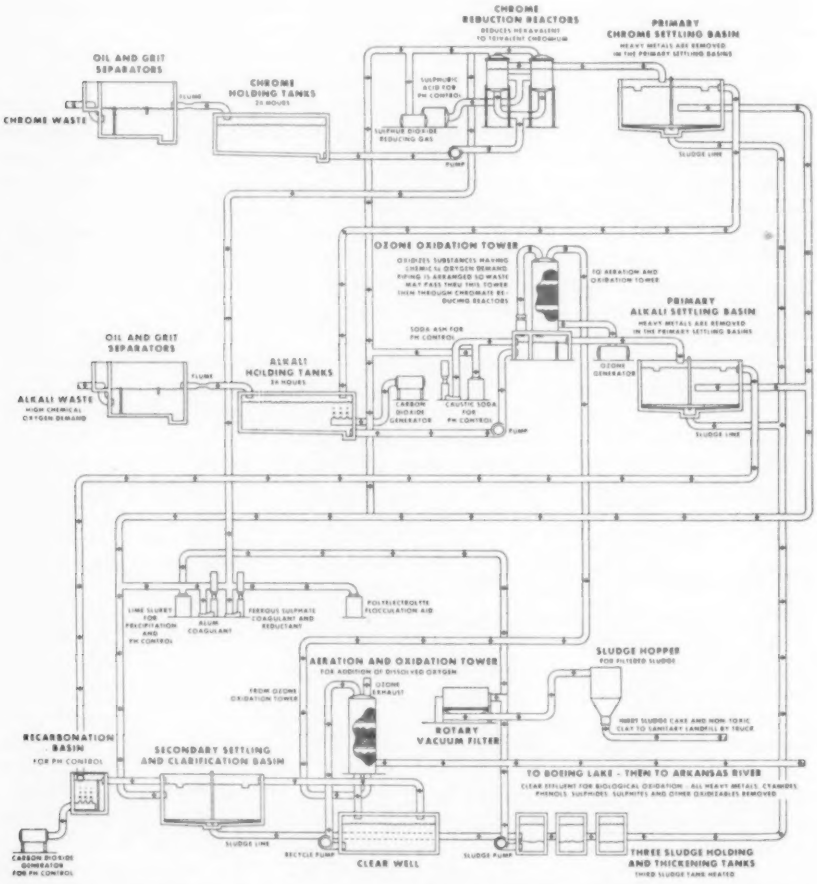

FIGURE 1.—Schematic diagram of the waste treatment process at the Boeing Airplane Company, Wichita, Kans.

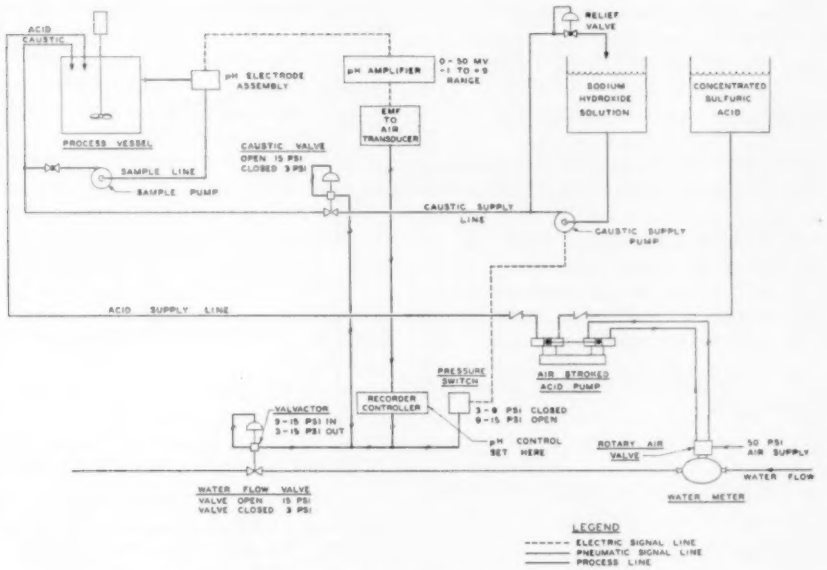

FIGURE 2.—Double-ended pH control system.

usual flocculants can also be added in the basin if desired. The waste in the third solids-contact basin contains anaerobic, sulfate-reducing bacteria. Since the waste at this point is quite high in sulfate, a slight reduction occurs. The waste then flows back into the plant to a clear well, where it is recycled over a final tower which absorbs the excess ozone plus oxygen from the first ozone absorption tower. The finished waste is discharged into a 7-acre lake, and then to a dry tributary of the Arkansas River. The final effluent is of high quality. Sludge from each of the three solids-contact basins is drawn off to sludge-thickening pits, and then pumped to a rotary vacuum filter. The dewatered sludge is hauled to a sanitary landfill area.

ORP Control Problems

The problem reported here is the chromate reduction process. When operations were started two years ago, it was determined that an oxidation-reduction potential of +160 to +200 Mv using platinum and calomel electrodes would be a reliable control set point for stoichiometric chrome reduction. This value was established from laboratory and pilot-plant tests, and is somewhat below the stoichiometric end point mentioned by Gard *et al.* (3).

During the first few months of operation, the process control system malfunctioned, at times using sizable excess quantities of sulfur dioxide and at other times passing hexavalent chromium through the system, all while the process was on automatic instrument control. These malfunctions usually occurred during periods of low concentration of hexavalent chromium ions in the feed stream. An unaccountable hysteresis effect appeared to vary the proper set point occasionally, and the process never seemed to become stable.

The equation for the potential, E, between the oxidized and reduced ions will help explain some of these difficulties.

The general form is:

$$E = E^0 + \frac{RT}{nF} \ln \left[\frac{\text{Ox}}{\text{Red}} \right] \quad \ldots\ldots (1)$$

Where

E^0 is a constant characteristic of the particular redox equilibrium being measured,

R is the gas constant,

T is temperature, ° Kelvin,

n is the number of electrons transferred, and

F is a free energy term.

For hexavalent chromium the redox equation is:

$$Cr_2O_7^{-2} + 14H^+ + 6e \rightleftharpoons 2Cr^{+3} + 7H_2O \quad (2)$$

and Equation 1 becomes, from Greer (4):

$$E = 0.902 + \frac{0.06}{6} \log \frac{[Cr_2O_7^{=}]}{[Cr^{+3}]_2} [H^+]^{14} \quad (3)$$

or it may be written:

$$E = 0.902 + \frac{0.06}{6} \log \frac{[Cr_2O_7^{-2}]}{[Cr^{+3}]^2} - 0.14[\text{pH}] \quad (4)$$

Greer (4) discusses this equation and cites experimental data. The pH factor explains the large sulfur dioxide demand at times, since this substance acts directly as an acid. Channon (5) has given the effects of sulfur dioxide and sodium metabisulfite on pH as shown in Figure 3.

The control process cycle then, can proceed as follows:

1. Entering chromates raise ORP and establish initial sulfur dioxide demand in accordance with Equation 3.

2. The sulfur dioxide added lowers the pH below the 2.5 control set point, the sulfur dioxide acting as an acid to increase the hydrogen ion concentration and reduce the chromate.

3. The ORP increases as a result of pH lowering, as given by Equation 3.

4. This ORP rise demands more sulfur dioxide (automatically fed) in response to ORP which has risen above the set point on the controller.

5. This reproduces step 2 and the process has already swung out of control. Acid feed has now shut off, and the process slowly returns to control as the pH is raised to the pH set point by the feed entering the process vessel. The net result is a tremendous artificial SO_2 demand, far beyond that needed for stoichiometric reduction. This lack of control stability seems to be unrecognized in the literature.

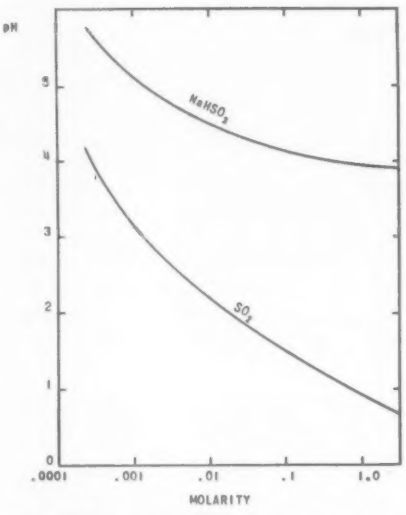

FIGURE 3.—Effect of sulfites on pH of aqueous solutions (after Channon (5)).

It had been assumed at the time of design that the waste stream would have a pH normally above 2.5 and, therefore, pH control was provided for lowering the pH only. Even though this assumption has generally been borne out, it is now apparent that it is equally necessary to provide control to raise the pH to the control point of 2.5, or, in other words, to prevent the over-acidification of the solution by the reductant, since the reductant affects both control systems independently: sulfur dioxide is an acid as well as a reducing agent. From Figure 2 it can be seen that SO_2 cannot be fed into a

solution more than 0.0015 M in SO_2 and at pH 2.5, without losing control.

The control of the reduction process using ferrous sulfate as reducing agent has been studied by Kelch and Graham (6), who have given the effects of pH, chromate concentration, and titration temperature of the electrodes. The pH of the reaction determines not only the EMF level, but also the sensitivity of the end point, that is, the slope of the plot relating EMF to reductant added. The addition of either ferrous sulfate or a sodium salt of sulfurous acid does not involve a pH lowering when the level is already at a reasonably low value, meaning that the system cannot lose control when one of these reagents is used.

Double End Point pH Control System

The reactor tank has a bottom feed and side discharge and is Koroseal-lined, pressure-tight, and vigorously stirred. The capacity is 1,500 gal, and at the maximum flow rate, the minimum reaction time is 4 min. Two feet below the liquid level of the reactor, a continuous recirculating stream is withdrawn and passed through the two ORP and one pH flow cells. The pH cell contains a standard glass electrode and a reservoir-type saturated calomel reference electrode. A recycle pump transfers a quantity of waste from the bottom to the top of the reactor. This stream is discharged approximately three feet below the liquid level in the reactor. Into this recycled stream is injected gaseous sulfur dioxide through a stainless steel ejector, dilute sodium hydroxide, ferrous sulfate, and the pH-ORP sample stream. The sulfuric acid is injected at the top of the reactor above the liquid level. The air-operated flow control valves are normally closed. Three psi control air pressure will begin to open the valves, and at 15 psi air pressure they will be fully open. The flow characteristics of these valves are equal percentage.

The pH signal from the electrodes is amplified after controlled adjustment to zero at the low end of the scale and gives a 0- to 50-Mv output, full scale.

The pH range is minus 1 to plus 9. The 0- to 50-Mv signal from the pH amplifier is changed to a 3- to 15-psi air signal by further control equipment. This air signal is then received by a recorder-controller. This controller is the instrument by which the pH is controlled in the reactor. If the pH indication on this instrument is above the set point, the output air signal increases, and conversely, if the indication is below the set point, the output air signal decreases. The output air signal is 30 to 15 psi.

The sulfuric acid pump is an air-stroked model. The 50-psi air signal is directed to the pump by a four-port rotary air valve turned by a water meter. This meter was modified by addition of the air valve.

The system operates as follows: Assume that a rise in pH is detected by the pH electrodes. This signal is then amplified and sent to the EMF-to-air transmitter which sends an increased air signal to the controller. The pH indicator on the control instrument then moves above the set point. This movement causes an unbalance in the controller, and in the effort to rebalance, the instrument air output signal is increased. This increase in air pressure is transmitted to the control on the sodium hydroxide valve, and on the water flow control valve. If the air signal is greater than 9 psi, the control on the water flow control valve begins to increase its air output signal to the valve, causing it to open.

The valve control takes a 9- to 15-psi air signal and gives an output air signal of 3 to 15 psi, but will not respond to a signal less than 9 psi. The water flow control valve will begin to open, allowing water to flow through the water meter, which turns a 4-port rotary air valve, allowing 50-psi air to stroke the acid pump at a rate proportional to the flow. The concentrated

sulfuric acid is pumped by the air-stroked pump from a 2,000-gal storage tank to the top of the reactor, and is discharged above the liquid level in the reactor. This acid is rapidly and thoroughly mixed by the reactor agitator, and the pH immediately begins to decrease, returning the system to the proper pH set point.

When the pH electrodes detect a drop in the pH due to high chrome loading or excess acid addition, the control instrument again detects the unbalance, this time with a lower air signal from the EMF-to-air transmitter, and in an effort to rebalance causes a lower output pressure from the control instrument. The lower air signal likewise is detected by both valve controls, but, in this case the sodium hydroxide valve responds. When the air pressure decreases to 9 psi or lower, a pressure switch closes turning on the sodium hydroxide pump. The control on the sodium hydroxide valve is set to respond to a 9- to 3-psi signal with an output signal of 3 to 15 psi. As the pressure decreases, this valve opens, allowing more sodium hydroxide to flow into the recycle stream to the reactor. At a 3-psi signal, the valve control and the sodium hydroxide valve are fully open. As soon as the pH returns to the set point, the output pressure from the controller returns to normal or to the mid-point close to 9 psi, and either sodium hydroxide or sulfuric acid will be added as demanded.

Discussion

Glasstone (7) gives for an oxidation reduction:

$$E_I - E_{II} = \frac{RT}{nF} \ln \frac{[\text{Ox } I]\ [\text{Red } II]}{[\text{Red } I]\ [\text{Ox } II]} \quad (5)$$

for the general reaction:

$$[\text{Red } I] + [\text{Ox } II] \rightleftharpoons [\text{Ox } I] + [\text{Red } II] \quad (6)$$

These equations describe equilibrium conditions. The use of activities relates the ionic strengths of the solution, which means that all ions in the solution affect the ORP.

The normal hexavalent chromium concentration is between 1 to 5 mg/l. This hexavalent chromium concentration is masked by a multitude of other components from various plant processes; theoretically, such things as: (*a*) other redox systems, (*b*) ionic strengths of various constituents, (*c*) polarization of electrodes, (*d*) organic compounds, and (*e*) temperature effects on the electrodes. All the above could all cause interferences in reproducing the control EMF, and thereby vary the proper control setting.

Lingane (8) discusses potential, various electrode combinations, interferences, side effects, and presents an extensive bibliography.

Standard dichromate solution normally is prepared with distilled water. Interfering ions are checked and corrected, yet it is proposed to obtain the same accurate measurement in a solution of mud, oil, PO_4^{---}, phenols, CN^-, Al^{+3}, floor washings, detergents, etc., just because the solution contains some hexavalent chromium. If the hexavalent chromium concentration is high enough to overshadow the interferences, some degree of control is possible; but when the interferences overshadow the chrome, there can be little or no control. The actual operating situation is usually somewhere between these extremes, so that while there may be some control, it is far from ideal, or usually not satisfactory.

Work has been done using many different electrode combinations, and it has been found that all can give erratic results, but the best results have been obtained from the Pt : Ag — AgCl couple at this plant. The plant has been able to reduce the consumption of reductant, and still consistently produce good water using this couple, providing that the chromate concentration is about 10 mg/l or greater. Some workers (9) (10) have found that gold is more suitable than platinum in acid-

chromate solutions. However, the environment in the reactor in this instance is on the acid-sulfite side, and no attack on platinum should take place. This would not be true in batch treating, where the electrodes are initially exposed to a strong acid chromate solution.

The Boeing plant uses an excess of reductant for the amount of chromate reduced. Chamberlin and Day (11) discuss the oxidation of sulfur dioxide by dissolved oxygen. This accounts for much of the excess sulfur dioxide used. Sulfite ions will react with other materials, including some organics which are often present in the waste.

The most logical means of control of sulfur dioxide feed for low chromium concentrations would appear to be by some continuous, but direct, spectrophotometric analysis for chromate itself. So long as chromate is present, the reductant should flow regardless of the actual ORP. The best answer appears to be installation of a process analyzer, utilizing either a spectrophotometric or colorimetric measuring instrument analyzing directly for chromate. Preliminary pilot-plant test results on this procedure have been encouraging, and it is suggested that chromate reduction process design include ORP controls to remove such higher chromate concentrations that will yield reproducible high millivolt potentials, and that a process analyzer be used for the fine control to remove the last 10 mg/l of hexavalent chromium. In any case, it is recommended that double end point pH control be used, or that a sulfite salt normally more alkaline than the reaction pH level may be used, particularly sodium metabisulfite.

Conclusions

In conclusion, it appears that the technology of the conventional treatment of dilute chromates contains several areas where further development would be of real benefit to industry in providing economical and efficient industrial waste disposal. Industrial waste treatment processes should be studied from an operational basis, and the common attitude of ignoring the plant once it has been built should be avoided by management. An ailing or inefficient treatment plant is usually a sign of poor management control. In the interests of lower costs and better effluents, practical research should begin when the plant start-up is begun, and plant operation, however complex, can be continuously improved by careful analysis of plant performance.

References

1. Selm, R. P., "Ozone Oxidation of Aqueous Cyanide Waste Solutions in Stirred Batch Reactors and Packed Towers." In "Ozone Chemistry and Technology," p. 66, Advances in Chem. Series No. 21, American Chemical Society, Washington, D. C. (1958).
2. "Methods for Treating Metal Finishing Wastes." Ohio River Valley Water Sanitation Commission (1953).
3. Gard, C. M., Snavely, C. A., and Lemon, D. J., "Design and Operation of a Metal Wastes Treatment Plant." *Sewage and Industrial Wastes*, **23**, 11, 1429 (Nov. 1951).
4. Greer, W. N., "Chromium Wastes—Recovery or Treatment? III. Instrumentation in Chromium Waste Treatment." *Sewage and Industrial Wastes*, **25**, 8, 930 (Aug. 1953).
5. Channon, H. B., "Chromium Wastes—Recovery or Treatment? II. Reduction of Chromium Wastes by Sulfur Dioxide." *Sewage and Industrial Wastes*, **25**, 8, 923 (Aug. 1953).
6. Kelch, J. L., and Graham, A. K., *Plating*, **36**, 1028 (1949).
7. Glasstone, S., "Textbook of Physical Chemistry." 2nd Ed., D. Van Nostrand Co., Inc., New York (1946).
8. Lingane, J. J., "Electroanalytical Chemistry." Interscience Publishers, Inc., New York (1958).
9. Baumann, F., and Shain, I., *Jour. Amer. Chem. Soc.*, **78**, 5550 (1956).
10. Anson, F. C., and Lingane, J. J., *Jour. Amer. Chem. Soc.*, **79**, 4901 (1957).
11. Chamberlin, N. S., and Day, R. V., "Technology of Chrome Reduction with Sulfur Dioxide." *Proc. 11th Ind. Waste Conf.*, Purdue Univ., Ext. Ser. **91**, 129 (1957).

Stream Pollution

MEASUREMENT OF TOXICITY OF ORGANIC WASTES TO MARINE ORGANISMS *

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Establishing criteria for quality of industrial effluents for disposal in the marine environment requires a somewhat different approach than in fresh water. Since most fresh water is potentially potable, taste, odor, and water quality in addition to effect of the waste to aquatic life become of prime importance; whereas, in brackish and sea water the main interest is in the effect of wastes on the marine ecological system. Historically, priority has been given to acute toxicity of waste to individual fish with little attention given to sub-lethal stresses on the entire community. Greater attention is now directed toward toleration of pollution (1).

Some organic wastes cause turbidity, color change, or slicks, and are aesthetically and usually ecologically undesirable. Effluents of these types can be detected easily and controlled visually or with relatively simple instrumentation; however, the dissolved toxic materials must be observed by either chemical or bio-assay techniques. Chemical evaluation of toxic components in effluent streams has received extended emphasis by some industries. These techniques are valuable when considering in-plant treatment but have not given satisfactory results in the field because chemical analyses usually give little or no information on the physiological state of the organisms, the history of the water, temperature, and other factors which become important in toxicity relations. Also, industrial effluents are chemically complex, and the necessary techniques for separating and determining all of these have not been developed, or chemical methods lack the sensitivity necessary to determine the small concentrations of materials which may be toxic. In complex wastes the presence of a number of different toxicants is expected. When mixed, these may create antagonisms or synergisms which will produce entirely different toxicity than that of pure components. As the mechanism of toxicity becomes better understood, chemical or biochemical techniques will be found increasingly useful. For the present, bio-assay procedures circumvent some of the problems of uncertainty by directly determining the effect of the waste on organisms, and can be done under conditions which simulate the natural environment to a very close degree.

Ideally, the effect of effluent streams should be studied in the waste-receiving water body. For this method to be effective, a large number of sampling stations must be taken over an extended period of time, and a rather complete knowledge of the hydrography, biota, chemistry, and mixing rates must be obtained. A number of

* Presented at the 136th Meeting, American Chemical Society; Atlantic City, N. J.; Sept. 13–18, 1959.

broad-scale studies have been undertaken in an attempt to determine changes in the types, kinds, and numbers of organisms in fresh water streams and lakes and in coastal estuaries and bays resulting from release of sewage and industrial wastes.

Rather extensive studies of many fresh water basins have been undertaken in recent years (2) (3) (4) (5) (6) (7). Along with these studies a number of specific techniques for indicating pollution have evolved (8) (9) (10). The effects of pollution on coastal waters have also received extensive attention (11) (12) (13) (14) (15) (16) (17) (18) (19) (20). Extensive studies of a more specialized nature have been undertaken to determine the effect of pollution on oyster and shellfish growth and mortality (21) (22) (23). Techniques for evaluating the over-all effect of pollution by *in situ* measurements of primary productivity of estuarine areas have been developed by Odum and Hoskin (24) and Park *et al.* (25); however, these techniques have not yet had extensive use as over-all pollution indicators. Such information, while giving valuable data on the effect of wastes on productivity of an area, does not necessarily reflect shifts that may occur due to change in kind of flora or fauna. Studies of this type coupled with detailed studies of the plankton community should give evidence of the over-all effect of added contaminants.

Because of the difficulty of obtaining adequate environmental data concerning changes in normal processes caused by pollution, it is usually expedient to supplement survey work with both chemical and biological evaluation of effluent streams. Coupling such information with characteristics of the estuary or receiving water systems allows the investigator to make recommendations for effluent clean-up and to predict the effects of the effluent on the marine community.

Bio-assays

Studies on application of bio-assays to toxicity of sewage and industrial wastes effluents are recorded (26) (27) (28) (29) (30) (31) (32). Relatively little work has been reported on similar data for marine fish. Daugherty (33) has proposed essentially the same method as adopted for fresh water fish with the exception of substituting a salt water species for the test organism. The usual method of reporting toxicity is based on the standard TL_m levels which indicate concentration of median lethality of the waste material to the test organism. These tests are useful in many cases as a control, but sub-lethal stress data are more useful in estimating the over-all effect of effluents in the aquatic system. To obtain these values many factors must be considered. Among these are temperature, dissolved oxygen, carbon dioxide, pH, alkalinity, history of organisms and water system, light penetration, ionic strength, presence of other organic contaminants, synergisms, and antagonisms.

In addition to standard bio-assays with the use of fish, a few special studies have been reported on the effect of effluents on other marine organisms or to fish in the actual environment. Chin and Allen (34) studied the toxicity of insecticides to the shrimp *Penaeus azteeus* and *Penaeus setiferus*. Hood *et al.* (35) have used the phytoplankton *Chlamydomonas sp., Porphyridium cruentum, Nitzschia closterium* (Ehr) Wm. Smith, and an unidentified diatom in determining the effect of chlorinated hydrocarbon wastes to photosynthesis. Vivier (36) used fish in live boxes in the receiving stream as an index of toxicity, and Harrington and Bidlingmayer (37) investigated the effects of dieldren on the toxicity of fish and invertebrates of a salt water marsh.

Relatively few data have been obtained on the sub-lethal stresses of organic wastes to organisms. For prac-

tical purposes data must be obtained which indicate whether the organisms endemic to an area can prosper as a species in an environment containing the toxic effluent material. To answer this question, it is necessary to look, not merely at the ability of the individual fish or organism to survive, but also at the ability to compete with other organisms of the environment for survival. The ability to reproduce, which may include access to spawning grounds, and the ability of eggs and young stages to develop and grow must be considered. Of basic importance to any study is the effect of contaminants on the ability of food organisms to survive in the polluted area.

In the marine system the phytoplankton represent a large portion of the total basic food supply; thus, studies with these organisms would seem to give information far more easily interpreted in terms of the efficacy of effluent treatment or dilution in an estuarine condition. Tests with organisms of trophic levels other than fish would also be of interest.

In any case, it is important that information be obtained on the metabolic effects of wastes on organisms rather than only their tolerance to acute toxicity. Such data may be obtained by measuring the effect of effluents on respiration, photosynthesis, or on specific enzyme systems of the organism. Weiss and Botts (32) investigated the effect of wastes on oxygen consumption rates of sunfish and minnows. Weiss (38) has determined the effect of organic insecticides on the enzyme system acetylcholinesterase. Previous preliminary work has been done (35) (39) (40) to determine the effect of wastes on the photosynthesis by marine phytoplankton. The results of a continuing study on the effect of industrial effluents on metabolism of crustacea and phytoplankton as compared to acute toxicity to marine fish and grass shrimp are given in this paper.

Experimental

Acute Toxicity

Cyprinodon variegatus.—Acute fish toxicities were determined by the tentative A.S.T.M. method, D 1345-54T, in which the estuarine minnow, *Cyprinodon variegatus*, was used as the test organism. Parallel experiments using this fish and *Fundulus similis* gave similar results with phenol as the toxic material. In all tests the oxygen concentration of the test bottle was measured daily and maintained at near saturation. Temperatures were maintained at $25 \pm 1°C$ and the fish were acclimated a minimum of 10 days and a maximum of 30 days from the time of gathering. Natural sea water obtained in Galveston Bay and adjusted to a chlorinity of 30 per cent was used as dilution water.

Palaemonetes.—The crustacean, *Palaemonetes* (grass shrimp), was used as a bio-assay organism employing the same techniques and conditions used for the fish.

Metabolic Effects

Artemia salina.—Commonly known as brine shrimp, these have been used by Hood (39) and by Okubo (41) as assay organisms for toxicity of effluents. This organism was selected because it is available as eggs which remain viable for several years and are easily accessible from pet shops. Hatching was accomplished by placing the eggs in sea water at a temperature of approximately 25°C for 24 hr. A detailed description of culturing methods is given by Bond (42). Organisms suitable for study of the effects of wastes on metabolic processes were prepared first by washing the shrimp eggs with several portions of sterile distilled water. Then the organisms were concentrated by removal of the water through a Buchner funnel. To a Fernbach flask equipped with a cotton plug and necessary glass tubing were added 1.5 l of 90-per cent sea water, and the

flask was autoclaved. After complete cooling, 3 g of the shrimp eggs were added to this culture medium and allowed to hatch at room temperature. Aeration was provided through a sterile cotton plug. To feed the shrimp, a few drops of a suspension of approximately 100 g of compressed baker's yeast mixed with 200 ml of sterile sea water were added every 24 hr. This method of culture, while not providing bacteria-free cultures, did provide an organism of low bacteria-count which was found suitable for respiration studies. To determine the effect of wastes on respiration, an aliquot of shrimp was removed from the culture flask and added to a 300-ml oxygen bottle containing gradient amounts of waste material. The bottles were completely filled with sterile sea water and allowed to stand for a period of 24 hr. The amount of oxygen consumed in each bottle was subtracted from the amount consumed in the control bottle, the difference representing the relative effect of waste concentration on the respiration of the shrimp. In cases where the waste interfered with the Winkler's reaction for DO, it was necessary to modify the experiment in order to circumvent this difficulty. In this case, the organisms were exposed to the waste material for a period of time, filtered, washed, and placed in sterile sea water for a growth period of approximately 24 hr. The oxygen utilization during this period was used as an index of the effect of exposure to the waste on the respiration of the organism.

Acute toxicity of wastes to brine shrimp was also determined. The number of living individuals in the culture medium before starting the experiment was determined by counting the total organisms in an aliquot of cultures, after killing with formalin, and subtracting from this the number of nonmotile organisms observed prior to killing. A ruled 2- × 3- × ½-in. lucite chamber and a 4-power binocular microscope were found satisfactory for counting. An aliquot of the shrimp culture was exposed to the waste material, and after a period of 24 hr the number of dead organisms in the culture was again estimated and the percentage killed was determined.

Phytoplankton.—Unicultures of the Chlorophyceae, *Platymonas* sp. and *Chlamydomonas* sp.; Xanthophyceae, *Mischococcus* sp.; Bacillariophyceae, *Nitzschia closterium* (Ehr) Wm. Smith and an unidentified diatom; and Rhodophyceae, *Porphyridium cruentum*, were used to determine the effect of wastes on photosynthesis. The nutrient medium used to grow and maintain the cultures consisted of Ketchum and Redfield's (43) Solution A, 2.0 ml; Ketchum and Redfield's (43) Solution B, 0.5 ml; Arnon's (44) micro-nutrients, 0.5 ml; Bold's (45) soil extract, 2.0 ml; $Na_2SiO_3 \cdot 9H_2O$, 0.0466 g; $Na_2MoO_4 \cdot 2H_2O$, 4×10^{-5} g; and 1,000 ml filtered sea water. The cultures were sub-cultured about one week prior to use in the experiments. Twenty-four hours prior to the experiment, the cultures were centrifuged, washed three times with sterile sea water, and to the subcultures was added 1×10^{-4} mole of potassium nitrate, and 3.7×10^{-4} mole KH_2PO_4 to the medium to insure rapid growth throughout the experiment. Solutions were adjusted to pH 8.2 and sterile conditions were maintained throughout.

Measurement of Inhibition to Photosynthesis

The amount of photosynthesis occurring in algal cultures in a period of 24 hr in the presence of gradient amounts of waste was determined by the method of Steemann-Nielsen (46). Sodium bicarbonate containing 0.5 μc of carbon-14 was added to a total volume of 150 ml of medium. The cultures were grown in presence of 900 foot-candles of incident light energy from fluorescent tubes. Dark bottles which did not permit light to enter

were used to determine absorption of carbon-14. After 24 hr the organisms were removed by filtration through 0.45μ membrane filters, washed with 1 N hydrochloric acid, desiccated, and the carbon-14 activity determined on a gas flow proportional counter. Efficiency of this machine has been determined to be about 33 per cent for carbon-14. The inhibition to photosynthesis caused by the waste was indicated by the reduced rate of carbon-14 uptake from that of the control maintained under exactly the same conditions.

Oxygen Evolution Measurements

In some cases the evolution of oxygen by the photosynthesizing organisms was used as an indication of photosynthesis. In this case, 300-ml BOD bottles were filled to the 250-ml mark with nutrient medium and the proper amount of waste material and water was added to fill the bottles. Parallel runs were made with dark bottles from which light was excluded. Cultures were incubated for a 24-hr period under conditions similar to that for carbon-14 uptake experiments after which the amount of oxygen in each bottle was determined. The difference between the oxygen in the light bottle and that in the dark bottle indicated gross photosynthesis of the cultures. This was compared to the controls as an index of inhibition. In the case of some wastes, interference to the obtained Winkler method for oxygen was observed. In these cases, the organisms were exposed to gradient concentrations of waste for a period of time, removed from the cultures, washed free of waste with sterile sea water, and then placed in standard BOD bottles in the presence of uncontaminated nutrient solution. The organisms were allowed to grow for a period of 24 hr, after which the oxygen was determined as above. The effect of exposure time on the waste material for the green algae *Chlamydomonas* sp. was reported earlier by Hood *et al.* (35). It was observed that the maximum effect due to exposure occurred in the first 60 min, and this exposure time was usually used in these studies.

Chlorophyll Determination

Chlorophyll concentration in the algae was determined by the method of Richards (47).

Wastes Investigated

Waste No. 1 was a lighter chlorinated hydrocarbon mixture containing some ethers and alcohol. The hydrocarbons were largely of 3 carbon units with limited substitution of chlorine. This mixture had a specific gravity of 0.95.

Waste No. 2 was black liquor obtained from Champion Paper and Fibre Company. It had a gravity of 1.265 g/cu cm at 60°C and contained 45.6-per cent solids; it had a pH of 13 and an alkalinity of 1.7 me/g of material.

Waste No. 3 was a heavy chlorinated hydrocarbon mixture. The hydrocarbons were largely of 3 carbon units with heavy substitution of chlorine. The mixture had a specific gravity of 1.34.

Waste No. 4 was an aqueous alkaline solution containing mercaptans and sulfides and was saturated with Waste No. 1 and No. 3. It had a specific gravity of 1.14.

Waste No. 5 was a mixture of heavy chlorinated hydrocarbons with an alkaline aqueous phase containing mercaptans and sulfides. This waste was produced at a later time than Wastes 3 and 4.

Waste No. 6 was reagent grade phenol.

Wastes immiscible with water were shaken vigorously with water, allowed to stand for 24 hr at 25°C and were centrifuged to separate phases. The water portion was considered saturated and dilutions of this material were used as test material. If the wastes consisted of water soluble and also im-

miscible wastes, a homogenized mixture of the two was added to water as above. The mixture of the two was considered saturated if immiscible material remained in contact with the aqueous phase.

Results and Discussion

Work on materials contained in Waste 3 gave the data presented in Figure 1. These data indicate that the test organisms which represent a rather broad spectrum of classes of marine plants do not respond to the same concentration levels with respect to this waste. *Porphyridium cruentum* and *Chlamydomonas* sp. appear to be most resistant of the organisms tested and even in this case the concentration of wastes of 10^{-4}-per cent saturated (5×10^{-5} g/l) affects photosynthesis adversely. In the case of *Mischococcus* sp. and the diatom, much lower concentrations are inhibitory. Experiments with other wastes have shown that with some wastes inhibition to all phytoplankton tested occurs at nearly the same concentration level, and at times the comparative sensitivity of the various organisms may shift depending on the nature of the waste material.

The effect of Waste No. 2, commonly known as black liquor, on photosynthesis of *Nitzschia closterium*, *Platymonas* sp., and the unidentified diatom is shown in Figure 2. Data on the per cent lethality of this waste to zooplankton obtained from a natural environment are also given. Concentrations of black liquor which completely inhibited photosynthesis (1 g/l) killed only about 25 per cent of the zooplank-

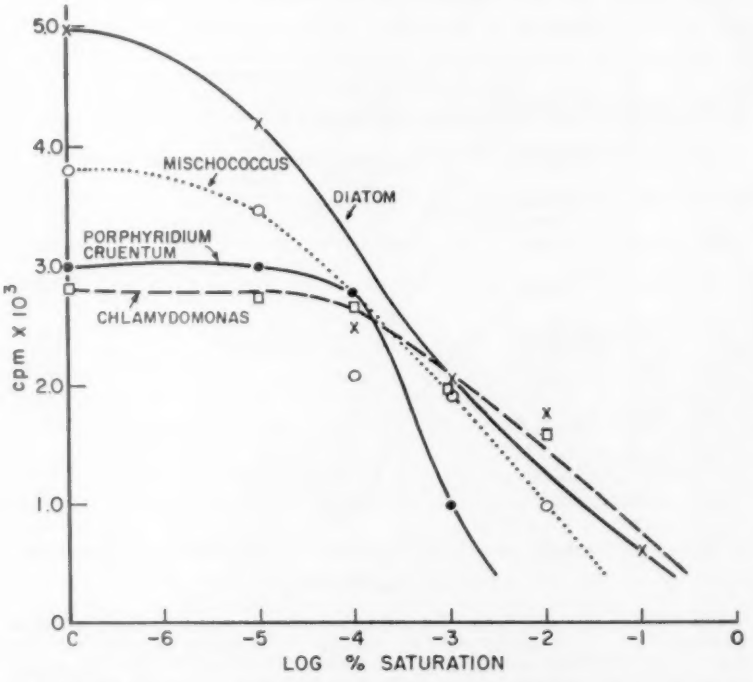

FIGURE 1.—Effect of Waste No. 1 on marine phytoplankton photosynthesis. C-14 uptake used as indicator of photosynthesis; 0.5 c $HC^{14}O_3$ added to each 150 ml culture; growing period, 22 hr.

ton organisms. Inhibition to photosynthesis occurred in *Platymonas* sp. organisms at a concentration of about 10^{-3} g/l; for *Nitzschia*, 10^{-2} g/l; and for the diatom, at about 0.16 g/l.

Ideally, zooplankton organisms endemic to the marine environment would be used for determining the effect of wastes on metabolism of this trophic level. There are few natural zooplankton that may be cultured in the laboratory in quantities sufficient to make these tests possible, and investigations were therefore undertaken to obtain an organism which would give representative data, and yet provide an organism readily available to the investigator. Investigations were thus undertaken with *Artemia salina*, the brine shrimp, as a test organism. In Figure 3, comparative data are presented on the effect of various wastes, including phenol, on the oxygen consumed by these organisms in the presence of gradient amounts of wastes. In the case of phenol, inhibition to respiration is initiated at 10^{-4} g/l and complete inhibition occurs at about 10^{-1} g/l. For comparison, data for the inhibition to photosynthesis of the phytoplankton *Platymonas* sp. are given for Waste No. 1. Brine shrimp appear to be much more resistant to inhibition to respiration than are the *Platymonas* sp. to photosynthesis. Only a 10^{-4}-per cent saturated solution initiates inhibition to photosynthesis by *Platymonas* sp.; whereas, little inhibition to respiration occurs even at the 10^{-2}-per cent saturation level for brine shrimp.

In Figure 4 comparative data are presented for lethality of Waste No. 5 to brine shrimp and fish, and also for the effect of the waste on respiration of the brine shrimp. These data indicate that brine shrimp are much less resistant to acute toxicity than fish but

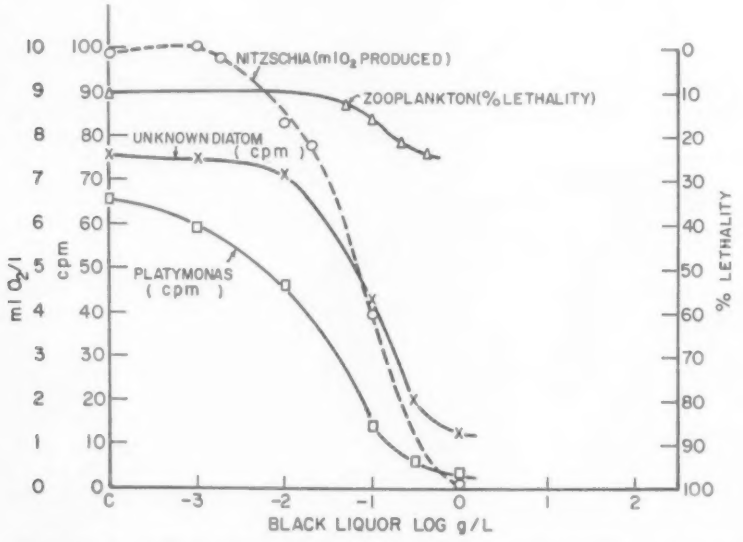

FIGURE 2.—Effect of Waste No. 2 (black liquor) on photosynthesis of marine phytoplankton. C-14 uptake used as indicator of photosynthesis for unknown diatom and *Platymonas* sp.; 0.5 c added to each 150 ml culture; growing period, 22 hr at 24°C. Oxygen evolution used as indicator of photosynthesis with *Nitzschia closterium*; growing period, 24 hr. Zooplankton obtained in ship channel at Institute of Marine Sciences Laboratory, Port Aransas, Tex. Exposure time, 120 min.

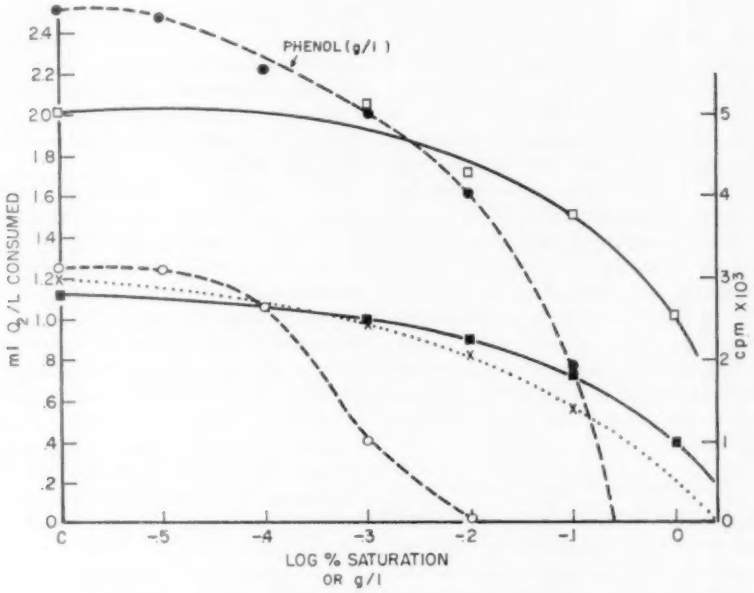

FIGURE 3.—Effect of different wastes on the respiration of *Artemia salina* as compared to effect on photosynthesis by *Platymonas* sp.

● - - - ● Phenol in g/l on inhibition of respiration of *Artemia salina.*

□——□ Waste No. 3 in per cent saturation on inhibition of respiration of *Artemia salina.*

■——■ Waste No. 1 in per cent saturation on inhibition of respiration of *Artemia salina.*

X · · · X Waste No. 4 in per cent saturation on inhibition of respiration of *Artemia salina.*

○ - - - ○ Waste No. 1 in per cent saturation on inhibition of photosynthesis of *Platymonas* sp.

Exposure time of *Artemia salina* to wastes was 2 hr; growth period was 24 hr.

inhibition to respiration in these crustaceans occurs at about the same concentration as does lethality to fish. These data suggest that the brine shrimp may yield results similar to fish toxicity data providing inhibition to respiration criteria are used in place of acute toxicity. The chief advantage of using these organisms lies in the ease of handling, relatively small samples of effluent required for tests, and the relative ease with which the data may be obtained. It is believed that tests based on these organisms could be applied to in-plant surveys to determine waste streams which are causing toxicity of plant effluents.

Further experiments were conducted to obtain a comparison of response to wastes between an additional member of the crustaceans, *Palaemonetes* sp., fish, and phytoplankton. In Figure 5 data are presented using phenol (Waste No. 6) as the toxic material. For this waste the TL_m for *Palaemonetes* occurred at a phenol concentration of about 90 per cent that for the fish. The phytoplankton showed some inhibition to photosynthesis at about 1 mg/l and 85-per cent inhibition occurred at 10 mg/l. The most marked difference between the inhibition to photosynthesis of phytoplankton and lethality to the other two organisms is the response of

the plants to very low concentrations of the phenol. Excessively high concentrations of phenol (200 mg/l) were required to completely inhibit photosynthesis. Similar data are given in Figure 6 for the response of the same organisms to Waste No. 5. In this case, the TL_m for *Palaemonetes* sp. occurred at a concentration of waste of 1.6-per cent saturated; whereas, for fish it occurred at 2.5-per cent saturated. *Platymonas* sp. showed greater sensitivity to the waste up to a concentration giving about 50-per cent inhibition to photosynthesis and then reached a plateau in which increasing concentrations caused relatively little increase in inhibition.

Summary and Conclusions

More sensitive tests of the sub-lethal stress placed on organisms by organic contaminants in sea water may be determined by measuring the inhibition to photosynthesis of several families of marine phytoplankton. These unicellular plants are found very sensitive to toxic materials although complete inhibition of photosynthesis may occur at greater concentrations of waste than is found lethal to fish.

Inhibition to respiration of *Artemia salina*, the brine shrimp, appears to occur at concentrations of a mixed waste of chlorinated hydrocarbon and alkaline sulfide which are lethal to fish, although lethality in these organisms occurs at a much higher concentration. In the phytoplankton *Platymonas* sp. photosynthesis was inhibited at concentrations of 10^{-4}-per cent saturation of a light fraction of chlorinated hydrocarbon waste (Waste No. 1); whereas, inhibition to respiration in *Artemia salina* occurred at about 10^{-2}-per cent saturation.

The crustacean *Palaemonetes*, commonly known as grass shrimp, are

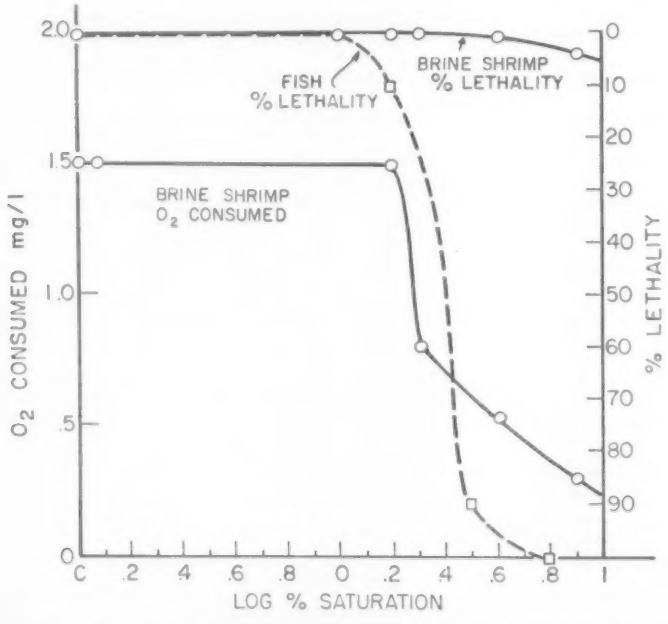

FIGURE 4.—Comparison of acute toxicity of *Artemia salina* and fish to inhibition of respiration of *Artemia salina* with Waste No. 5. Exposure time of *Artemia salina* to waste was 24 hr; growth period was 24 hr.

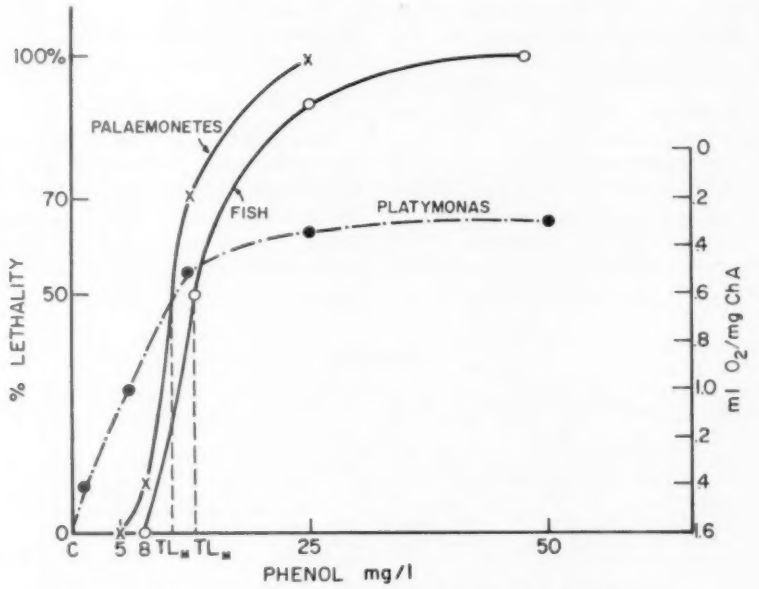

FIGURE 5.—Comparison of acute toxicity of phenol to *Palaemonetes* and fish, and to inhibition of photosynthesis in *Platymonas* sp. Photosynthesis indicated by evolution of oxygen because of Cholorophyll A in culture.

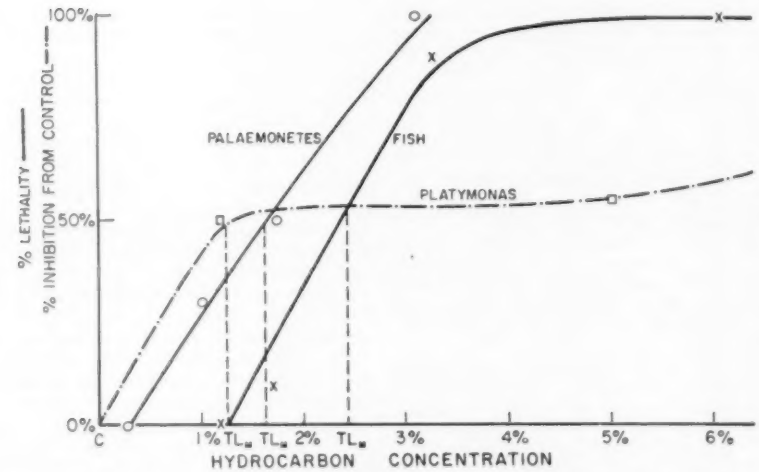

FIGURE 6.—Comparison of acute toxicity of heavy chlorinated hydrocarbon to *Palaemonetes* and fish, and to inhibition of photosynthesis in *Platymonas* sp. Photosynthesis indicated by per cent difference between C-14 uptake by control and sample. 0.5 μc $HC^{14}O_3^-$ added to each 150-ml culture.

somewhat more sensitive to wastes than are *Cyprinodon variegatus*, the fish used in these studies.

It is concluded that experiments on the metabolic effects of wastes give more useful information on the tolerance of important ecological groups of the environment than can be obtained from acute toxicity of wastes to fish or to other individual organisms. It is suggested that further work on metabolic effects of wastes, perhaps to include enzyme inhibition, will provide a better understanding of the effect of industrial effluents on the environment.

Acknowledgments

This paper is a contribution from the Department of Oceanography and Meteorology of the Agricultural and Mechanical College of Texas, and is based in part on work done through sponsorship of the Shell Chemical Corporation.

References

1. Beak, T. W., "Toleration of Fish to Toxic Pollution." *Jour. Fish. Res. Bd. Canada*, **15**, 559 (1958).
2. Cramer, J. W., Johnson, W. E., Ferguson, G. E., Metzler, D. F., Detweiler, J. C., and Ramsey, J. B., "The Missouri River Panel Discussion." *Jour. Amer. Water Works Assn.*, **48**, 8, 942 (Aug. 1956).
3. Love, S. K., "Quality of Surface Waters of the United States, 1951. VII–VIII. Lower Mississippi River Basin and Western Gulf of Mexico Basins." U.S. Geol. Survey Water Supply Paper No. 1199, p. 490 (1955).
4. Ludzack, F. J., Ingram, W. M., and Ettinger, M. B., "Characteristics of a Stream Composed of Oil Refinery and Activated Sludge Effluents." *Sewage and Industrial Wastes*, **29**, 10, 1177 (Oct. 1957).
5. Schneller, M. V., "Oxygen Depletion in Salt Creek, Indiana." *Invest. Ind. Lakes and Streams*, **4**, 163 (1955).
6. Vavasour, G. R., and Blair, A. A., "Pollution Survey of Humber Arm and Exploits River." *Jour. Fish. Res. Bd. Canada*, **12**, 682 (Sept. 1955).
7. Wiley, A. J., Lueck, B. F., Scott, R. H., and Wisniewski, T. F., "Cooperative State-Industry Stream Studies—Lower Fox River, Wisconsin." *Sewage and Industrial Wastes*, **29**, 1, 76 (Jan. 1957).
8. Ingram, W. M., "Use and Value of Biological Indicators of Pollution: Fresh Water Snails and Clams." *Trans. Seminar Biol. Problems in Water Poll.*, Robert A. Taft San. Eng. Center, Cincinnati, Ohio, p. 94 (1957).
9. Patrick, R., "Diatoms as Indicators of Changes in Environmental Conditions." *Trans. Seminar Biol. Problems in Water Poll.*, Robert A. Taft San. Eng. Center, Cincinnati, Ohio, p. 71 (1957).
10. Reisch, D. J., "Effects of Pollution on Marine Life." *Ind. Wastes*, **2**, 114 (1957).
11. Braarud, T., and Foyn, E., "Nitrite in Polluted Sea Water." *Avhandl. Norske Videnskaps-Akad, Oslo, I, Mat.-Naturv. Kl.*, **3**, 3 (1951).
12. Larson, L. C., "Pollution of Los Angeles and Long Beach Harbors." *Jour. San. Eng. Div., Amer. Soc. Civil Engrs.*, **82**, SA1, 891 (Feb. 1956).
13. Maxwell, B. E., "Hydrobiological Observations for Wellington Harbour." *Trans. Royal Soc. New Zealand*, **83**, 493 (1956).
14. Nusbaum, I., and Miller, H. E., "The Oxygen Resources of San Diego Bay." *Sewage and Industrial Wastes*, **24**, 12, 1512 (Dec. 1952).
15. Pearson, E. A., "An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge." State of California, State Water Pollution Control Board, Pub. No. 14 (1956).
16. Rechnitzer, A. B., and Limbaugh, C., "An Oceanographic and Ecological Investigation of the Area Surrounding the Union Oil Company Santa Maria Refinery Outfall, Oso Flaco, California." IMR Reference 56-5 (Sept. 1956).
17. Romer, H., "The Health Department's Role in New York Harbor Pollution Control." *Sewage and Industrial Wastes*, **28**, 12, 1495 (Dec. 1956).
18. Tully, J. P., and Waldichuk, M., "Pollution Study in Nanaimo Harbor." *Progr. Rep., Pac. Coast Sta. Fish. Res. Bd. Canada*, **97**, 14 (Dec. 1953).
19. Waldichuk, M., "Effluent Disposal from the Proposed Pulp Mill at Crofton, B. C." *Progr. Rep., Pac. Coast Sta. Fish. Res. Bd. Canada*, **102**, 6 (1955).

20. Waldichuk, M., "Pulp Mill Pollution in Alberni Harbor, British Columbia." *Sewage and Industrial Wastes*, **28**, 2, 199 (Feb. 1956).
21. Collier, A., "Oysters, Their Growth Rate and Survival When Retained Under Crude Petroleum." Monograph for Gulf Oil Company (Sept. 1953).
22. Humble Oil and Refining Co., "Scientists Stalk Oyster Killers." *The Humble Way* (1956).
23. Wise, R. I., Winston, J. W., and Culli, G., "Factors of Sewage Pollution of Oyster Beds in Galveston Bay." *Amer. Jour. Pub. Health*, **38**, 1109 (Aug. 1948).
24. Odum, H. T., and Hoskin, C. M., "Comparative Studies on the Metabolism of Marine Waters." *Pub. Inst. Marine Sci.*, **5**, 16 (Dec. 1958).
25. Park, K., Hood, D. W., and Odum, H. T., "Diurnal pH Variation in Texas Bays and Its Application to Primary Production Estimation." *Pub. Inst. Marine Sci.*, **5**, 47 (Dec. 1958).
26. California Water Pollution Board, "Water Quality Criteria." Pub. No. 3 (1952); and Addendum No. 1 (1954).
27. Doudoroff, P., Anderson, B. G., Burdick, G. E., Galtsoff, P. S., Hart, W. B., Patrick, R., Strong, E. R., Surber, E. W., and Van Horn, W. M., "Bio-assay Methods for the Evaluation of Acute Toxicity of Industrial Wastes to Fish." *Sewage and Industrial Wastes*, **23**, 11, 1380 (Nov. 1951).
28. Doudoroff, P., and Katz, M., "Critical Review of the Literature on the Toxicity of Industrial Wastes and Their Components to Fish. I. Alkalies, Acids, and Inorganic Gases." *Sewage and Industrial Wastes*, **22**, 11, 1432 (Nov. 1950).
29. Doudoroff, P., and Katz, M., "Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish. II. The Metals, as Salts." *Sewage and Industrial Wastes*, **25**, 7, 802 (July 1953).
30. Ellis, M. M., "Detection and Measurement of Stream Pollution." *U. S. Bur. Fish. Bull.*, **22**, 365 (1937).
31. Henderson, C., and Tarzwell, C. M., "Bio-Assays for Control of Industrial Effluents." *Sewage and Industrial Wastes*, **29**, 9, 1002 (Sept. 1957).
32. Weiss, C. M., and Botts, J. L., "Factors Affecting the Response of Fish to Toxic Materials." *Sewage and Industrial Wastes*, **29**, 7, 810 (July 1957).
33. Daugherty, F. M., Jr., "A Proposed Toxicity Test for Industrial Wastes to be Discharged to Marine Waters." *Sewage and Industrial Wastes*, **23**, 8, 1029 (Aug. 1951).
34. Chin, E., and Allen, D. M., "Toxicity of an Insecticide to Shrimp." *Texas Jour. Sci.*, **9**, 220 (1957).
35. Hood, D. W., Stevenson, B., and Jeffrey, L. M., "Deep Sea Disposal of Industrial Wastes." *Ind. Eng. Chem.*, **50**, 889 (1958).
36. Vivier, P., "Comments on the 'Fish Test'." *Bull. Centre Belge Etude et Document. Eaux* (Belgium), No. 15, 61 (1952).
37. Harrington, R. W., Jr., and Bidlingmayer, W. L., "Effect of Dieldrin on Fishes and Invertebrates of a Salt Water Marsh." *Jour. Wildlife Management*, **22**, 76 (1958).
38. Weiss, C. M., "Response of Fish to Sub-Lethal Exposures of Organic Phosphorus Insecticides." *Sewage and Industrial Wastes*, **31**, 5, 580 (May 1959).
39. Hood, D. W., "The Disposal of Chlorinated Hydrocarbons and Other Chemical Wastes at Sea." Fourth Report on Deep Sea Disposal, Texas A. & M. College, Ref. 57-20T (June 1957).
40. Hood, D. W., "Waste Disposal in Marine Waters." *Proc. Sixth Conf. Coastal Eng.*, p. 607 (1958).
41. Okubo, K., "Study on the Bioassay Method for the Evaluation of Water Pollution." *Bull. TOKH—Reg. Fish. Res. Lab.*, **18**, 31 (1957).
42. Bond, R. M., "Culture Methods for Invertebrate Animals." Comstock Publishing Co., Ithaca, N. Y. (1937).
43. Ketchum, B. H., and Redfield, A. C., "A Method of Maintaining a Continuous Supply of Marine Diatoms by Culture." *Biol. Bull.*, **75**, 165 (1938).
44. Arnon, D. I., "Microelements in Culture Solution Experiments with Higher Plants." *Amer. Jour. Bot.*, **25**, 332 (1938).
45. Bold, H. C., "The Cultivation of Algae." *Bot. Rev.*, **8**, 66 (1942).
46. Steemann-Nielsen, E., "The Use of Radioactive Carbon (C-14) for Measuring Organic Production in the Sea." *Jour. Cons. Intl. Explor. Mer.*, **43**, 117 (1952).
47. Richards, F. A., "The Estimation and Characterization of Plankton Populations by Pigment Analyses. I. The Absorption Spectra of Some Pigments Occurring in Diatoms, Dinoflagellates, and Brown Algae." *Jour. Marine Research*, **11**, 147 (1952).

DEFINITIVE DIAGNOSIS OF FISH MORTALITIES*

By Edward M. Wood

Gig Harbor, Washington

The first manifestation of a water pollution problem frequently is a fish kill. Considering the far reaching implications of a serious fish mortality, it is strange, indeed, that methods for determining exact cause of death are so little applied to fishery problems.

Fish mortalities can be classified generally as either acute or chronic. In the first class fall those incidents wherein some catastrophe is imposed on a watershed over a very short period of time (less than 24 hr) resulting in a massive fish kill which is immediately apparent to all. In the second case, the only manifestation of mortalities may be a generally declining status of the resident populations.

The Ohio River Valley Water Sanitation Commission (1) enumerates three major causes of fish mortalities: (*a*) natural causes, (*b*) mechanical agents, and (*c*) polluting substances. Deaths due to mechanical agents can frequently be recognized by the gross appearance of the fish. However, in the past it generally has not been possible by an examination of the affected fish to separate deaths caused by natural agents from those due to polluting substances. This paper describes recent advances in this field and discusses their application to the diagnosis and prevention of fish kills.

While acknowledged to be obvious, the importance of accurate diagnosis of fish kills cannot be overemphasized. With the rapidly expanding population encroaching in various ways on the natural habitat of fish, this resource treads a narrow line between survival and extinction. It is essential, therefore, that factors which are inimical be recognized and corrected. At the time of an acute mortality, or in the face of slowly dwindling populations, it is much too easy to select and accuse the obvious—which is usually one or more industries utilizing the same water resource. It is too little realized that this is an era which has been characterized by changing concepts of fishery management. In almost every instance these newer concepts are unproved and unchallenged; some of the concepts might, in fact, be suspect in themselves as a cause of decreasing populations. Acute massive fish kills are frequently associated with urban or industrial waste disposal. It is unusual, however, that the precise offender can be identified, particularly when multiple industries or several communities utilize the same water resource. It cannot be overemphasized that the purpose of such identification is not for restrictive or punitive regulation, but for the prevention and correction of undesirable conditions.

Factors in Diagnosis

There are two important sources of information for diagnosis of fish mortalities—environment and the victim.

Environment

For approximately 50 years emphasis has been placed on various techniques for studying the environment in which a fish kill has occurred. It is apparent that certain biological data are invaluable. If a mortality occurs at a certain place or time which coincides with a specific toxic effluent,

* Presented at the Ninth Pacific Northwest Industrial Wastes Conference, University of Washington; Seattle, Wash.; Apr. 2–3, 1959.

the implications are apparent (but on occasion, misleading). The study of food chain organisms may also be helpful. Usually, however, modern techniques rely on the bio-assay in its various ramifications. In very general terms, an attempt is made under laboratory conditions to determine the toxic levels of specific components thought to be involved in a given mortality. The concentration of these components at the site of mortality is then computed and a projection of the laboratory data extended to the field conditions. The errors involved are well recognized by the many workers in this field. It is obvious, for example, that in acute mortalities, a sample of the water and its toxic component may not be obtained before the toxic agent has disappeared. Further, the avoiding reactions of fish in nature may invalidate the results of aquarium studies where avoidance is impossible. In addition, it is seldom possible to predict the final effect on fish of sublethal exposures. Finally, the interaction of natural disease processes and artificial toxic factors is virtually inaccessible to evaluation.

Victim

The second major source of information is the victim. Can an examination of a dead fish reveal the cause of its death? The answer is perhaps most apparent by an analogy with the field of medicine. When the traumatized victim of an automobile accident is viewed, there is seldom any serious question as to cause of death. When a man dies of unknown causes, however, his examination is ultimately conducted by a trained medical pathologist. Here, under highly specialized techniques, his tissues receive a searching microscopic examination. The lesions caused by specific diseases, whether these are viral, bacterial, protozoan (or other parasitic) are usually easily identified. If toxic factors are involved, these also leave their distinctive changes on specific tissues. When necessary, chemical analysis under microscopic scrutiny provides the definitive answer. With a tremendous background of research and experience, the medical pathologist has become the mainstay in definitive diagnosis of unknown mortality in man.

Fish Pathology

Does pathology, then, offer similar information in the diagnosis of unknown mortalities in fish? In 1953 the U. S. Fish and Wildlife Service initiated a program of pathological research on fishery problems. In the ensuing years an extensive study on the normal histology of wild and hatchery fish was conducted (2). This was followed by a series of studies on the specific pathology of the common diseases affecting fish (3)(4)(5)(6)(7)(8)(9)(10)(11)(12)(13)(14)(15). It is now apparent from these results that pathology offers a definitive method which is unexcelled for the diagnosis and investigation of fish diseases. The diagnosis of mortalities due to toxic materials is equally well substantiated (16)(17). In addition, the techniques of pathology have been applied to such diversified problems as the evaluation of wounds in salmon found moribund in the vicinity of dams or stream obstructions; the determination of age of net scar marks in ocean-caught fish; the interrelationship of oyster mortality, pollution, and parasitism; and the pathology of salmonids caused by hydrogen sulfide, pulp mill effluents, certain fungicides, and domestic sewage.

Sufficient information is now available for the trained fishery pathologist to diagnose most of the common fish diseases. Thus, if an acute mortality is due to a natural organism, the examination of a single representative sample should be sufficient to establish this point. If the mortality is due to a toxic compound, the problems are concerned with the adequate

collection of affected fish and the preparation and selection of control specimens for microscopic comparison. Thus, it is usually necessary to subject fish to those toxicants or effluents thought to be implicated and to compare the pathology of these fish to that of the observed mortality.

Examples of Manifestations

Any factor which is sufficiently toxic to cause either sickness or death in fish will, with certain exceptions, cause specific and distinctive changes in at least one tissue or organ. Countless examples are available, but for purposes of illustration a few of the lesions encountered in the gills alone will be described. The normal gills under high magnification are composed of countless delicate, fingerlike projections or lamellae. Each lamella consists of a minute capillary surrounded by a single layer of epithelial cells which represents the only barrier between the blood of the fish and the surrounding water (Figure 1). It is across this barrier that the gaseous exchange which permits fish to live in water takes place. Any factor which increases the thickness of this barrier handicaps the respiratory exchange. The manner in which these gill changes take place is an accurate indicator of the agent causing the change. Bacterial disease, for example, creates an irregular distribution of hyperplastic lesions and normal tissue as shown in Figures 2 and 3. A deficiency of certain vitamins causes a single gradually encroaching hyperplastic lesion that progresses from the tip of the gill filament to the base (Figure 4). Hydrogen sulfide causes a layer of edema to form under the epithelium which swells the lamellae

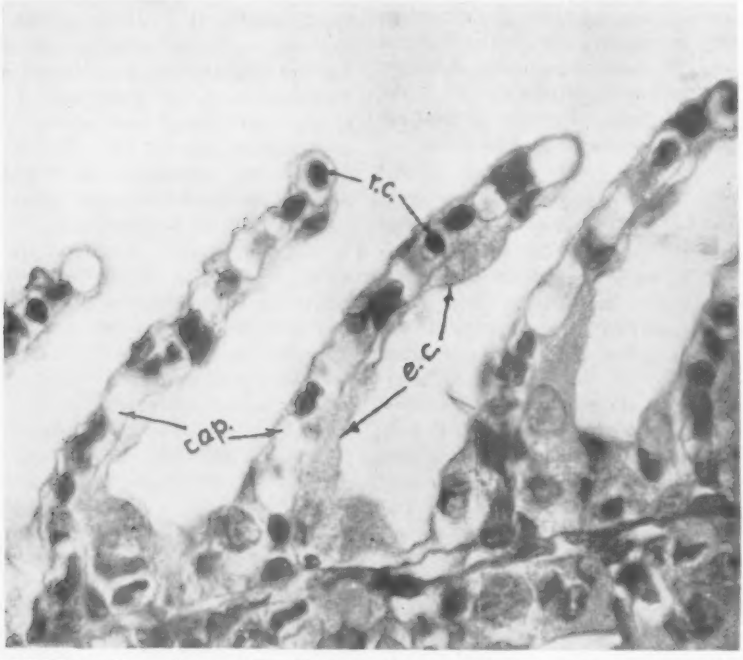

FIGURE 1.—Normal trout gill. Note the single capillary (cap.) in each lamellae, the nucleated red blood cells (r. c.), and the single layer of epithelial cells (e. c.) which separates the blood from the surrounding water (approx. × 2150).

FIGURE 2.—Bacterial gill disease. The scattered hyperplastic lesions prevent normal gaseous exchange by the involved lamellae. The condition is entirely analagous to bronchial pneumonia in the human (approx. × 115).

to a non-functional state (Figure 5). Various heavy metals lead to intense mucous formation which covers the lamellae. Frequently the metal ion is precipitated in this mucous and can be specifically identified by histochemical tests. Protozoan parasites often

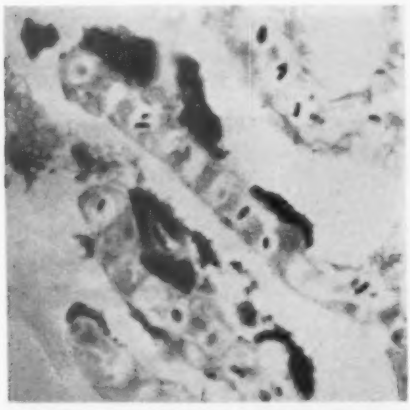

FIGURE 3.—A very early stage in bacterial gill disease. A special stain has been used to demonstrate the bacteria which are seen as dark masses surrounding the lamellae. The typical hyperplasia is just beginning to form the lesion seen in Figure 2 (approx. × 460).

encyst and create a focus of thickened epithelium around themselves (Figure 6). Additional, as yet unidentified, toxic factors are associated with specific hemorrhagic lesions (Figure 7).

Special Problems

It would be unrealistic to imply that all mortalities can be identified by pathological techniques. Deaths caused by disease are the easiest to recognize, followed closely by toxic materials which cause specific lesions. The question arises about those compounds which cause only low oxygen

FIGURE 4.—Nutritional gill disease. A deficiency of the vitamin, pantothenic acid, causes this fusion of the lamellae at the tips of the gill filaments (approx. × 115).

concentrations which, in turn, cause death. Mortality due to anoxia can be identified pathologically, but if several compounds are responsible for the low oxygen concentrations in question, then the skillful selection of samples will be required if the true cause is to be identified. In special cases a specific lesion may not be observed. Revealing data may still be obtained by studying the pathology of fish exposed to suspected effluents since each of these may cause specific lesions and thus eliminate itself as a candidate.

Pathology also offers an excellent tool for the investigation of fish prob-

lems characterized only by slowly dwindling populations and without acute massive mortalities. Washington coastal streams are typically populated by migratory salmonids that spend a major part of their life cycle in the ocean. When an expected run of adult fish fails to materialize, the possible causes of such failures are almost limitless. As previously pointed out, the hatchery conditions under which these fish are produced may in themselves be so adverse that the planted fish are incapable of survival. In their transit down the stream the

FIGURE 5.—A gill exposed to hydrogen sulfide. The epithelium of the lamellae is swollen and edematous, seriously compromising the respiratory exchange (approx. × 115).

young fish are exposed to countless parasitic and predatory organisms from which they may have been protected in the hatchery. At each point where a toxic effluent is encountered, they may avoid it, or they may incur tissue damage sufficient to cause death at some later date. Finally, the dangers which these fish encounter in the ocean are almost totally unevaluated. It should be apparent that no one technique is the panacea to fish diagnostic problems. The careful monitoring of fish throughout their life cycle, however, by pathological examination,

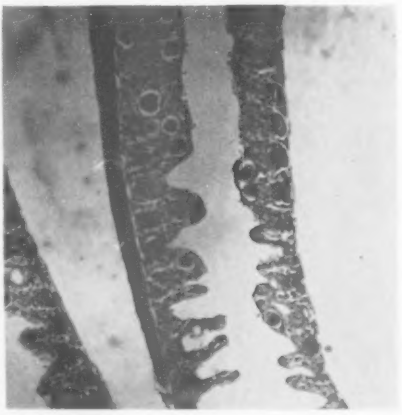

FIGURE 6.—Protozoan gill disease. A microsporidian has caused the fusion of the lamellae resulting in heavy mortalities of hatchery fish (approx. × 115).

offers great promise in the detection of those critical areas in which tissue damage is first incurred.

Actual Procedure

The only absolutely essential measure is the collection and adequate preservation of representative specimens. Ideally, the best specimens are those

FIGURE 7.—Hemorrhagic gill disease. An unknown toxic factor causes this characteristic appearance. The capillaries of many lamellae have ruptured, creating microscopic, blood filled balloons (approx. × 115).

fish which are near death but not dead. The greater the interval between death and preservation, the poorer are the chances for accurate identification of cause of death. Not less than five specimens should be collected. Adequate preservation implies placing the specimens in a fixative which precipitates the proteins and stops bacterial and enzymatic decomposition. For a number of technical reasons, Bouin's solution is preferred for fish tissues. This consists of a mixture of 75 parts of aqueous saturated picric acid, 25 parts of formaldehyde (saturated solution), and 6 parts of glacial acetic acid. If this is unavailable, the second choice is 10-per cent formalin. If neither is available, freezing is a poor third choice. A final important point about preservation is that when fish are placed in fixatives, they should be opened completely from anus to gills and not more than 1 volume of fish should be placed in 5 volumes of fixative. Whenever possible, a competent fishery biologist or pathologist should be called immediately to analyze the many biological aspects of the mortality which might not be recorded by the untrained observer.

Summary

The use of pathology procedures in conjunction with biological studies and bio-assay techniques will do much to solve the complex problems involved in the accurate diagnosis of fish mortalities. This, then, is the first essential step, but only the first, in the logical solution of disposal and pollution problems which materially affect fish and other aquatic populations.

References

1. "Procedures for Investigation of Fish Kills." Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio (1956).
2. Wood, E. M., Yasutake, W. T., Woodall, A. N., and Halver, J. E., "Body Composition of Salmonoid Fishes. I. Histological and Chemical Studies." *Jour. Nutrition*, **61**, 465 (1957).
3. Wood, E. M., Snieszko, S. F., and Yasutake, W. T., "Infectious Pancreatic Necrosis in Brook Trout." *A.M.A. Arch. Pathol.*, **60**, 26 (1955).
4. Wood, E. M., Yasutake, W. T., and Lehman, W. L., "A Mycosis-Like Granuloma of Fish." *Jour. Infect. Diseases*, **97**, 262 (1955).
5. Wood, E. M., and Yasutake, W. T., "Histopathology of Fish. I. Techniques and Principles." *Progr. Fish-Cult.*, **17**, 166 (1955).
6. Wood, E. M., and Yasutake, W. T., "Histopathology of Fish. II. The Salmon Poisoning Fluke." *Progr. Fish-Cult.*, **18**, 22 (1956).
7. Wood, E. M., and Yasutake, W. T., "Histopathologic Changes of a Virus-Like Disease of Sockeye Salmon." *Trans. Amer. Micro. Soc.*, **75**, 85 (1956).
8. Wood, E. M., and Yasutake, W. T., "Ceroid in Fish." *Amer. Jour. Pathol.*, **32**, 591 (1956).
9. Wood, E. M., and Yasutake, W. T., "Histopathology of Kidney Disease in Fish." *Amer. Jour. Pathol.*, **32**, 845 (1956).
10. Wood, E. M., and Yasutake, W. T., "Histopathology of Fish. III. Peduncle (Cold-Water) Disease." *Progr. Fish-Cult.*, **18**, 58 (1956).
11. Wood, E. M., and Yasutake, W. T., "Histopathology of Fish. IV. A Granuloma of Brook Trout." *Progr. Fish-Cult.*, **18**, 108 (1956).
12. Wood, E. M., and Yasutake, W. T., "Histopathology of Fish. V. Gill Disease." *Progr. Fish-Cult.*, **19**, 7 (1957).
13. Snieszko, S. F., Wood, E. M., and Yasutake, W. T., "Pancreatic Necrosis in Trout." *A.M.A. Arch. Pathol.*, **63**, 229 (1957).
14. Yasutake, W. T., and Wood, E. M., "Sporozoans of Northwestern Salmonids." *Jour. Parasit.*, **43**, 633 (1957).
15. Wood, E. M., and Yasutake, W. T., "Tissue Damage in Salmonids Caused by *Halisidota argentata*, Packard." *Jour. Parasit.*, **42**, 544 (1956).
16. Wood, E. M., Yasutake, W. T., and Snieszko, S. F., "Sulfonamide Toxicity in Trout." *Trans. Amer. Fish. Soc.*, **84**, 155 (1955).
17. Wood, E. M., Yasutake, W. T., and Johnson, H. E., "Acute Sulfamethazine Toxicity in Young Salmon." *Progr. Fish-Cult.*, **19**, 64 (1957).

THE OPERATOR'S CORNER

OPERATION OF SEWAGE TREATMENT PLANTS

Readers of the Federation Journal will find on the following pages the first chapters of Manual of Practice No. 11—*Operation of Sewage Treatment Plants*. This new manual is the work of a subcommittee of the Federation's Sewage and Industrial Wastes Practice Committee. To this subcommittee, so ably headed by Mr. Donald M. Pierce, goes our gratitude for completing an unusually difficult task.

The Sewage and Industrial Wastes Practice Committee, under the chairmanship of Dr. M. M. Cohn, has had this project on its agenda for many years, and even though it is largely by accident, the appearance of this manual immediately following the publication of the design manuals on treatment plants and sewers is thoroughly logical.

Because of the manual's size and importance, a plan for serial publication was proposed and quickly approved by the appropriate Federation committees. Serialization will make the material available to members at an earlier date and perhaps most important, will give the reader an opportunity to comment on sections of the manual as they appear. After the appearance of the last installment around the middle of 1961, all comments received will be evaluated and the final revision will be reprinted as a single book of about 160 pages, the usual size of a Journal issue.

A tentative list of the chapter headings is given below:

1. The Operator
2. Characteristics of Sewage
3. Sewage Pumping and Pumping Stations
4. Screening
5. Grit Removal
6. Separate Sedimentation
7. Sludge Digestion
8. Sludge Conditioning
9. Sludge Dewatering
10. Sludge Heat Drying and Incineration
11. Sludge Disposal
12. Gas Collection and Utilization
13. Imhoff Tanks
14. Trickling Filters
15. Activated Sludge
16. Stabilization Ponds
17. Intermittent Sand Filters
18. Disinfection and Chlorination
19. Effects of Industrial Wastes
20. Records and Reports
21. Safety Practices
22. Flow Measurements
23. Sewage Sampling

While the title suggests that the manual is specific for "Sewage Treatment Plants," it should be noted that the operating procedures are in general the same ones used at many plants treating industrial wastes. Thus, the manual will find equal application among industry members of the Federation.

With this and other installments of the manual, your comments are invited. Please send them directly to the Federation office. They will be shared with the subcommittee producing the manual before the final revision is made.

The members of the task force responsible for this project are listed below. All of these men deserve the sincere thanks of the Federation membership.

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Operation of Sewage Treatment Plants

1. OPERATOR RESPONSIBILITIES

In recent years, the public generally has expressed increased interest and respect for sewers and treatment works. No longer are these facilities off-bounds in polite conversation, to be ignored and shunned by society. Today they occupy a position of prominence and general interest, particularly where the municipal budget is to be increased substantially for a new or expanded collection system, pumping station, or treatment plant. The taxpayer is acutely aware of the cost of these facilities, but if he should forget momentarily, he is firmly reminded whenever he pays his monthly or quarterly charges for service or examines the special entry on his tax bill.

Interest and support for a sound and well-managed system and treatment plant, regularly giving needed service to the home owner, business establishment, and industry, continue to grow as the community grows. Desire for a clean community grows stronger each year and the demand for cleaner streams, for a host of reasons, is becoming equally strong.

This growing recognition of the importance of proper wastewater collection and treatment naturally has its effect on the operator and his job. In some small- and medium-sized communities, the superintendent of the sewage treatment plant occupies the most difficult and demanding position on the municipal organization chart. Increasingly, the public and municipal administrative officials are demanding skilled performance by superintendents, in addition to reliability and hard work.

1.1 OPERATOR INCENTIVES

This growing public interest and recognition also provide powerful incentives for the operator. To some, the major attraction is the physical plant with its machinery, mechanisms, controls and processes, its buildings and grounds; to others, it offers an opportunity to work in a well-equipped, modern laboratory. Still others find a challenge for special aptitudes, knowledge, and skill in converting ever-changing raw materials into acceptable end products. Many find satisfaction in doing a job which few others can do as capably.

Today, with increasing emphasis everywhere on the importance of a clean community, many operators find incentives and rewards in the major role they play in keeping the environment free of nuisance and the streams useful and enjoyable as streams should be. If he is at all conservation-minded, he may derive great satisfaction from knowing that he is helping to protect a stream from pollution, and in some cases reclaiming a stream for recreational pursuits such as swimming, boating, and fishing, and for wildlife.

Many operators find in their jobs the right combination of relationships with their fellow workers and employer. Their job may also provide them with the measure and kind of security they seek.

These are good, sound reasons for

selecting employment in a sewage treatment plant and there are many others equally good. The work offers many incentives and compensations, but it does impose many demands, some severe and exacting. These the successful man will accept as challenges worth meeting.

1.2 SCOPE OF RESPONSIBILITY

As in most public service positions, the superintendent of a sewage treatment plant is responsible to one or more public officials and to the public at large. Frequently, as the person in responsible charge, he is required to submit operation reports directly to the state health department and receives requests and instructions from their field engineers and chemists. He has another set of responsibilities to members of his own staff at the plant. It may seem sometimes that these several responsibilities are utterly incompatible and it is on this point that he must assume one of his greatest responsibilities —making seeming incompatibility disappear.

The requirements and objectives of the job vary with such factors as plant size, complexity, nature and size of waters receiving the plant effluent, and community attitude. Yet in many respects the same broad considerations prevail at all plants. In broad context, each plant superintendent should be responsible for:

1. Effective and efficient continuous operation of the plant;
2. Maintenance of adequate plant records;
3. Providing responsible officials with information essential to planning, budgeting, and management of the plant;
4. Fostering good working conditions and incentives for employees; and
5. Establishing and maintaining good public relations.

Discharging these responsibilities requires teamwork among all who are associated with the management of the treatment plant. The superintendent is the captain of the team at the plant, but he is also a member of another team whose captain may be the mayor or public works director. Also on this latter team may be the water superintendent, street superintendent, city engineer, and other department heads. It is the superintendent's responsibility to keep this second group informed on his needs and accomplishments, and how his program fits in with theirs under a similar set of rules. He is the professional from whom the other members expect the answers—all of the answers—about the treatment plant. He must have knowledge and understanding of all of the elements of operation to provide these answers.

1.3 CHANGING RESPONSIBILITIES

During the period of design, construction, and startup, the superintendent should become familiar with each element of his plant, including equipment. He should make specific recommendations to the responsible officials for correction of deficiencies and for justifiable improvements. He should, when appropriate, help the designing engineer to understand more fully some of the operational aspects which affect the design. During this same period, he should develop a training program for members of his new staff so that they will be ready and capable of performing the minimum essential operations when the plant is placed in service, and he must develop

work schedules and assignments. Establishment of sound employee relationships during this period is important.

It is essential during this early period for the superintendent to make his needs and accomplishments known to his superiors. Concurrent with these operations, the plant superintendent must become familiar with the character of the sewage. Particular attention must be given to industrial wastes which may have a deleterious effect upon plant structures or processes. If any are found, the superintendent should advise the responsible city official and cooperate with him and the industry to develop a satisfactory means of disposal.

After the plant has been in operation for several months, procedures, methods, and results should become reasonably well stabilized and the superintendent should have more time to devote to management of the facilities. He should acquire a thorough knowledge of his plant, the sewage it treats, and the effects of the effluent on the receiving stream. He should keep informed about improved operating and maintenance practices. He should encourage his staff to acquire the information they need to discharge present and future responsibilities. His records should accurately reflect the results of efficient and economical treatment and they should serve as a basis for decisions on replacement of parts and future enlargements or alterations.

The plant superintendent should always strive to anticipate needs for increased expenditures. He should advise the proper official of these needs to permit early planning and budgeting if possible. He should be prepared at all times to give a clear account of his needs and of the condition of the plant. As the load on the plant approaches its capacity or as the plant facilities depreciate, he should anticipate the need for its enlargement or replacement.

There are other responsibilities which are equally important, but none is more important than the maintenance of good public relations. The superintendent's pride of achievement and the knowledge of the importance of his operations form a sound starting point. High morale and sense of responsibility among his staff are essential. The next building block is a stable relationship with the official to whom he is immediately responsible, a relationship based on understanding and respect. From this base, the superintendent can develop public interest and understanding of the sewage treatment operation through the coordinated efforts of the total team at the plant. But he and his staff will merit and receive the respect of their fellow workers and the general public only after they begin to carry out fully their responsibilities.

2. CHARACTERISTICS OF SEWAGE

Sewage, the liquid flowing through a sewer, has been aptly defined as the spent water of a community. It contains the wastes resulting from the use of water for domestic, commercial, and industrial purposes and such ground or surface water as may enter the sewer. Domestic sewage, derived principally from dwellings, business buildings, institutions and the like, contains wastes from the bathroom, laundry, and kitchen, while industrial waste is the liquid waste from processes employed in industrial plants. Sanitary sewage may contain both domestic sewage and industrial wastes.

2.1 PHYSICAL CHARACTERISTICS

Normally, the physical characteristics of a waste can be evaluated by measuring temperature, odor, color, turbidity, and variations in flow.

2.11 Temperature

It is important to know the temperature of sewage and normally it is a few degrees higher than the water supply of the community. There will be minor fluctuations from the normal, but there need be little concern about them. When an appreciable increase in temperature is observed, one can usually attribute it to the discharge of a hot industrial waste; an appreciable drop is many times attributed to infiltration of storm or surface water.

Temperature of the waste has an effect on sedimentation and biological activity. As the temperature increases, the viscosity decreases and sedimentation is improved. Biological activity—the reason sewage decomposes—is a function of temperature and time. As the temperature increases in the range from 45 to 105°F, bacterial activity increases. Therefore, decomposition time increases as temperature decreases and vice versa.

2.12 Odor

The odor of fresh sewage may be described as musty, which is not especially offensive. However, when the sewage is old and begins to putrefy, the odor becomes very objectionable. Old sewage will have the characteristic rotten egg odor of the hydrogen sulfide that is being produced. Sometimes unusual odors may be discerned in the sewage and these usually can be traced to an industrial waste.

2.13 Turbidity and Color

Fresh sewage normally has a high turbidity and appears grayish. When the incoming sewage is black, it usually is the result of partial decomposition. Other colors such as green (pea cannery waste, for example) or yellow (chrome waste) are caused by industrial discharges.

2.14 Variations in Flow

Sewage flow to the plant will have variations in rate broadly classified as hourly, daily, and seasonal. Usually, the smaller the community, the greater the variation in flow. This variation will depend to a large extent on the habits of the people and the characteristics of the collection system, i.e., combined or separate, number and location of lift stations, sewer grades, and quality of construction. The type and operation of industrial plants served by the wastewater collection system will also have an influence on the fluctuations in flow.

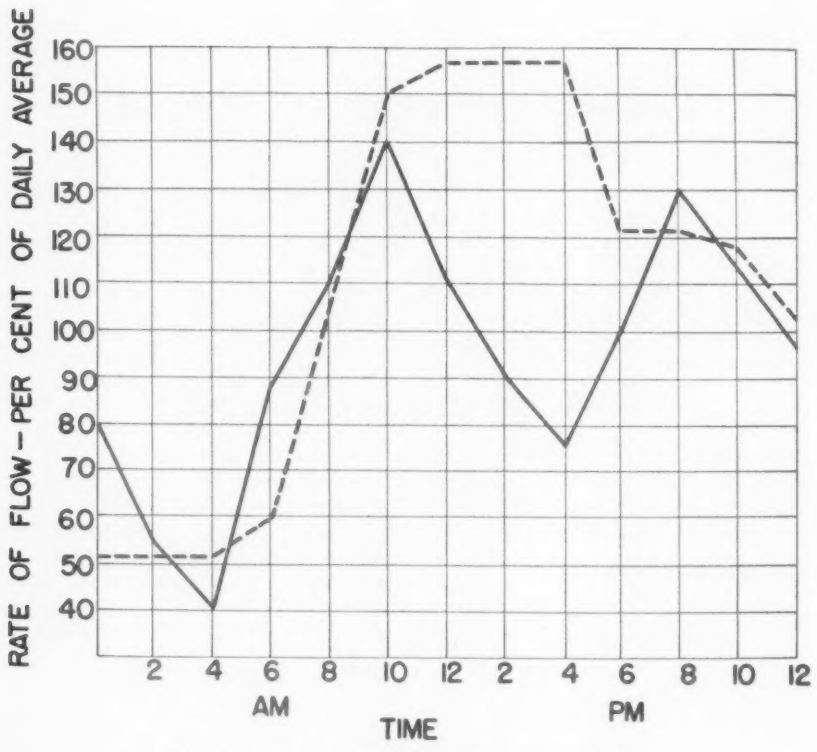

FIGURE 1.—Typical hourly variation in sewage flow.

Generalizing on the expected hourly variations in flow, it is usually minimum after midnight and maximum between 7 AM and 3 PM. Where the collection system is long, the maximum rate of flow at the plant will occur late in the morning or early in the afternoon. The hourly variation in flow may range from 50 to 200 per cent of the average. Figure 1 shows the hourly variation in sewage flow from a typical small community.

2.2 CHEMICAL CHARACTERISTICS

Characterizing chemical properties of sewage may be divided into large groups—inorganic and organic.

2.21 Inorganic

Inorganic constituents in sewage consist primarily of sand and the dissolved mineral matter which is contained in the community water supply and the ground water that infiltrates the collection system. Industrial wastes of some types also add inorganic chemicals to the sewage. The common mineral matter comprises sulfates, carbonates, and chlorides of calcium, magnesium, sodium, potassium, and iron. These salts ordinarily are not as troublesome as the organic compounds. However, they can affect the treatment process. For example, iron salts have been precipitated in aeration tanks of activated sludge plants and in trickling

filters, causing clogging of the air diffusers in the first case and clogging of the filter media in the second.

2.22 Organic

The organic fraction of sewage is composed largely of proteins, carbohydrates, and fats.

The proteins and their metabolic and decomposition products are the nitrogen-producing materials in the wastes. Proteins contain carbon, hydrogen, nitrogen, and oxygen, and sometimes phosphorus and sulfur. The percentage of each varies to some extent in the different proteins. A typical protein, eggs, is composed of about 53 per cent carbon, 7 per cent hydrogen, 15 per cent nitrogen, 2 per cent sulfur, and 23 per cent oxygen. The main source of nitrogen in sewage is urea, $CO(NH_2)_2$, which rapidly decomposes to carbon dioxide and ammonia. Proteins may also contribute sulfur to the waste, which in its reduced form may be evolved as hydrogen sulfide gas.

Carbohydrates contain carbon, hydrogen, and oxygen. Typical carbohydrates are the sugars and starches. These materials are the first to be broken down by the bacteria, with the production of organic acids. Thus in old sewage, the pH usually will be lower than in fresh sewage because of the breakdown of carbohydrates.

Fats also contain carbon, hydrogen, and oxygen in a ratio of approximately 76 per cent carbon, 12 per cent hydrogen, and 12 per cent oxygen. This material is present in kitchen, tannery, and packing house wastes. Fats make sewage treatment difficult; they coat the walls of tanks and channels, and, if not removed, decompose and produce unpleasant odors. They are responsible for the scum on sedimentation units and coat other organic particles which in turn tend to clog filters.

2.3 CHARACTERISTICS COMMONLY MEASURED

The wastes received at most plants contain all of the chemical constituents already mentioned and, in some cases, others. Ordinarily, not all of these constituents are of direct interest to the plant operator. He is more interested in concentrations of solids, biochemical oxygen demand, pH, and nitrogen.

2.31 Solids

Solids in sewage are classified in different ways such as fixed and volatile, suspended and dissolved. The concentrations of the different classifications will vary to a considerable degree in different sewages. Data in Table 2–1 show the concentration of the different types of solids in a medium-strength sewage. The concentration of the various components will vary from 50 to 150 per cent of the values shown.

TABLE 2-1.—Solids in a Medium-Strength Sewage

Solids Classification	Concentration (mg/l)
Total	500
Volatile	350
Fixed	150
Suspended	300
Volatile	250
Fixed	50
Dissolved	200
Volatile	100
Fixed	100

2.32 Biochemical Oxygen Demand

Biochemical oxygen demand or BOD is the most important characteristic of a waste from the operator's and engineer's standpoint because it is one of the best indicators of sewage strength. It is really a measurement of the oxygen required for the biochemical oxidation of the organic matter at a given time and temperature. To determine the total BOD, an incubation period of several weeks would be required. Therefore, in the interest of conformity, the 5-day BOD at 20°C is ordinarily determined in accordance with

the current edition of *Standard Methods for the Examination of Water and Wastewater* published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation.* The BOD of domestic sewage usually will vary from 100 to 300 mg/l. Garbage increases this value and ground and surface water lower it.

2.33 pH

The pH is a measure of the hydrogen-ion concentration of a liquid. The higher the concentration, the lower the pH. It will vary from 1.0 to 14.0, with 7.0 being the pH of a neutral solution. Values greater than 7.0 are found in alkaline solutions and those less than 7.0 are found in acid solutions. At pH values below about 6.0 or above about 9.0, the organisms which stabilize wastes are inhibited. As an illustration, the pH of sludge in a digestion tank must be maintained very close to 7.0 if effective performance is to be expected.

2.34 Nitrogen

Nitrogen appears in organic wastes in various forms, depending on the degree of waste stabilization. For sewage, there are four kinds of nitrogen which are commonly determined: free ammonia, organic nitrogen, nitrate nitrogen, and nitrite nitrogen. These different forms constitute the total

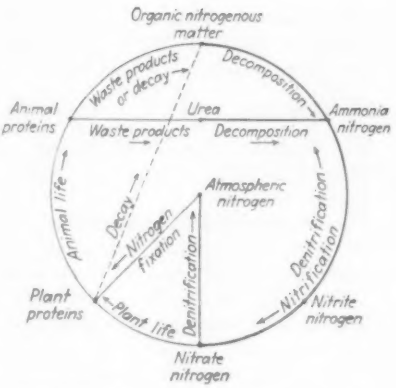

FIGURE 2-1.—The nitrogen cycle.†

nitrogen content. Fresh, cold sewage should be relatively high in organic nitrogen and low in free ammonia. A stale, warm sewage should be relatively high in free ammonia and low in free nitrogen. The sum of the two should be unchanged in the same sewage. Nitrates and nitrites may be present in fresh sewage, but always in low concentrations. However, in treated sewage their concentrations will usually be higher. Nitrites are not stable and are either reduced to ammonia or oxidized to nitrates, and their presence indicates that change is in progress. The nitrogen cycle depicted in Figure 2–1 will progress either clockwise or counter clockwise, depending on whether free oxygen is available.

* Available through the American Public Health Association, 1790 Broadway, New York 19, N. Y.

† From *Sewage-Treatment Works* by Clarence E. Keefer and published by McGraw-Hill Book Co., New York.

2.4 MICROORGANISMS

Microorganisms are present in sewage in a great many forms. From the standpoint of the operator, they may be classified in two broad groups: those which carry on the work of sewage purification through their natural processes and those which are capable of creating disease and infection in man or animal.

The presence and the work done by organisms which aid in sewage purification depend on the available food supply and environmental conditions. These organisms may in one case oxidize a substance and in another, reduce it. For example, in an anaerobic environment, organisms may reduce urea, hydrolize protein or cellulose, emulsify

fats, reduce nitrates and sulfates by withdrawing oxygen for their own use, and produce methane, carbon dioxide, and ammonia. When present in an aerobic environment, they add nitrites and nitrates, carbon dioxide, and water. Methods used for harnessing these organisms for the common good are discussed in later chapters.

Organisms capable of creating disease and infection in man and animal must always be assumed present in sewage. This means the operator needs to exercise care in handling sewage to protect his own health and the health of the community. Disinfection of treated sewage before discharge to the receiving waters is discussed in detail later in this manual.

DEEDS AND DATA

"To be conscious that you are ignorant is a great step toward knowledge."—Benjamin Disraeli

Highlights from the Annual Reports of Boise, Idaho, Cincinnati, Ohio, East Bay Municipal Utility District, Oakland, Calif., Fort Wayne, Ind., Grand Rapids, Mich., Jeffersontown, Ky., Kenosha, Wis., Middlesex County Sewerage Authority, Sayreville, N. J., New Britain, Conn., Racine, Wis., South Bend, Ind., Toledo, Ohio, and Winnipeg, Manitoba.

A. J. WAHL, *Superintendent, Boise Idaho;* ARTHUR D. CASTER, *Principal Sewage Disposal Engineer, Cincinnati, Ohio;* E. E. ROSS, *Manager, Sewage Disposal Division Engineer, EBMUD, Oakland, Calif.;* PAUL BRUNNER, *Superintendent, Fort Wayne, Ind.;* HUNTLEY DELANO, *Superintendent, Grand Rapids, Mich.;* M. C. SWEENEY, *Plant Supervisor, Jeffersontown, Ky.;* FRANK I. VILEN, *Superintendent, Kenosha, Wis.;* SOL SEID, *Chief Engineer, Middlesex County Sewerage Authority, Sayreville, N. J.;* JOHN R. SZYMANSKI, *Superintendent, New Britain, Conn.;* THOMAS T. HAY, *Superintendent, Racine, Wis.;* LOUIS P. BOURDON, *Superintendent, South Bend, Ind.;* JAMES E. FROOK, *Commissioner, Division of Sewage Disposal, Toledo, Ohio;* and N. S. BUBBIS, *General Manager, Greater Winnipeg Sanitary District, Winnipeg, Man.*

Activated Sludge

Toledo joined the growing ranks of former primary plants that have added secondary treatment. Its activated sludge units went into operation during March 1959, and, as with any new facility, transitional problems are demanding close attention and vigorous action.

An early difficulty was caused by the quadrupling of sludge quantities over primary operation and the consequent wear on already-worn sludge pumps. One further complication is the rapid filling of the sludge disposal area. Heat-exchange capacity also is less than needed and both gas production and digester capacity have been reduced because of it.

• The use of the thickener tank for concentrating waste activated sludge at Grand Rapids has been discontinued. Even under close supervision, the thickened sludge seldom exceeded 2.5 per cent solids. Now, the wasted sludge is sent to the primary tanks, and a 5-per cent sludge is transferred to the digesters.

• *Sphaerotilus* infected the Boise plant in February and normal operation could not be resumed until the middle of April. The growth first showed up in the sewers in early February following sewer-flushing operations.

Bar Screen

A converted cable-operated bar screen at EBMUD, now chain-operated, was modified further by raising the foot sprockets so that the rake engaged the screen several inches above the bottom of the screen channel. This change eliminates halting of the rakes at this point by stones and other collected debris.

Chlorination

Corrosive and irritating fumes which hitherto accompanied prechlo-

rination at the EBMUD treatment plant have been eliminated. This triumph is the result of years of attempts, the most recent of which had to do with the problem of diffuser location and size. These experiments demonstrated that fuming did not occur when a larger number of smaller diameter orifices were used in the diffusers. The orifice diameter was reduced to produce a velocity of at least 10 fps. Solution velocities of this magnitude seem to create sufficient turbulence for complete mixing.

Also, a study was made to determine if the oxidation-reduction potential of the raw sewage could be used to control prechlorination. Sewage received from the north interceptor had a positive ORP, which is abnormal, but the south interceptor carried sewage with negative ORP. The combined flow has an ORP of about − 50 mv. Industrial wastes are believed to influence the ORP of the north interceptor.

The study revealed that, contrary to accepted theory, there was poor correlation between sulfide concentration and ORP.

Despite the abnormal sewage, the incentive of automatic control of prechlorination is so great that further study will be made.

Industrial Wastes

One day in December 1958, a metal finishing company notified the Grand Rapids treatment plant of its wish to dump 700 gal of spent copper cyanide. Arrangements were made for slow discharge to the sewer and simultaneous dilution with large amounts of water. Plant surveillance consisted of sampling the influent, primary effluent, and final effluent at 30-min intervals. The highest concentration of cyanide found at the plant was 8.6 mg/l; the maximum copper concentration was 3.6 mg/l. Thirty-six hours later, deterioration of the activated sludge process was evident; two days after the dump, the BOD removal was down to 56 per cent against 80 per cent for the previous day. Each successive day the sludge density index decreased (sludge volume index increased) until the process failed completely.

Several attempts were made to unload the sludge by pumping it back to the primary tanks, but the sludge was so light and fluffy it would not settle. The thickeners had to be returned to service in a last-ditch attempt to get rid of the light material. Even this procedure was not entirely successful, for at the end of a week there was still a vestige of light floc. Experience suggests that the quickest way to purge the facilities of poor-settling sludge is to divert the full flow of primary effluent through the aeration tanks without returning any sludge to the primary tanks.

• Five thousand gallons of concentrated hydrochloric acid entered a Fort Wayne sewer following the rupture of the acid storage tank. The company furnished more than five tons of soda ash for neutralization.

• Laboratory-scale digesters at EBMUD were used to study the effects of cellulosic felt mill wastes on sludge digestion. Comparisons were made between felt mill–sewage sludge mixtures and normal sewage sludges.

Gas production in felt mill–sewage sludge mixtures was only 57 per cent of the production in the control digesters, even though the volatile solids loadings in both units were about the same. The conclusion was that the felt mill waste should not be permitted entry to the sewer system.

Odor Control

Odor control at Winnipeg is now in the investigatory stage. Chlorination at various locations on the collection system is being evaluated, and at the plant, a masking agent is being sprayed to the atmosphere above the clarifiers. In both experiments, extraneous diffi-

TABLE I.—Operating Results from Six Activated Sludge Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Efficiency of Treatment (%)						Grit Removed (cu ft/mil gal)
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent		Primary Unit		Secondary Unit		Over-all		
										BOD	SS	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
1. Boise, Idaho	12/59	29,700	6.1	11.4	0.9	205	—	—	—	100	199	10	15	28	51	86	85	90	92	—
2. Fort Wayne, Ind.	12/58	146,000	22.0	38.9	13.0	148	—	—	—	238	384	15	15	7	8	91	92	92	93	2.9
3. Grand Rapids, Mich.	6/59	202,870	38.0[c]	—	—	180	60	—	—	104	151	32	56	24	32	59	46	67	60	0.7
4. Jeffersontown, Ky.	12/59	2,500	0.3	—	—	203	—	—	—	140	145	10	9	40	—	88	—	92	93	10.6
5. South Bend, Ind.	12/59	140,000	33.3	—	—	238	—	—	—	102	139	7	12	15	55	93	90	87	88	1.3
6. Toledo, Ohio	12/59	303,000[g]	56.0	123.6	37.8	—	63	—	—	223	455	37	98	29	45	75	56	84	78	2.9

Treatment Plant	Primary Sedimentation				Activated Sludge								Disinfection	
	Surface Overflow Rate (gpd/sq ft)	Raw Sludge			BOD Loading (lb/day/1,000 cu ft)	Air Use (cu ft/lb of BOD removed)	Air Use (cu ft/gal of sewage)	Aeration Period (hr)	Return Sludge (%)	Mixed Liquor		Sludge Index	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
		Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)						DO (mg/l)	SS (mg/l)			
1. Boise, Idaho	—	1,025	—	—	—	2,010	1.7	—	29	2.3	1,087	0.3	3.0	—
2. Fort Wayne, Ind.	2,210	760	2,010	4.4	32.5	592	0.8	6.2	32	2.5	2,979	1.1	—	—[d]
3. Grand Rapids, Mich.	—	475	1,337	4.5	37.0	827	0.3	2.4	12	4.2	597	1.3	—	
4. Jeffersontown, Ky.	—	450	—	—	—	—	2.0	8.1	—	4.5	5,900	0.8	—	—
5. South Bend, Ind.	870	537	1,480	4.4	26.2	930	0.6	4.0	26	3.7	2,195	1.5	—	—
6. Toledo, Ohio	—	—	—	5.9	—	—	1.6	3.5[h]	49	2.2	4,000	2.1	—	—

Treatment Plant	Sludge Digestion								Gas					Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Supernatant Volume (cu ft/mil gal of sewage)	Supernatant Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)	Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
1. Boise, Idaho	—	—	94	—	—	6.9	—	—	2.2	—	—	—	—	—	—	—	—	28.04
2. Fort Wayne, Ind.	—	49	—	—	—	7.1[a]	306	2,800	1.1	6.5	89	—	—	—[b]	—	—	—	25.09
3. Grand Rapids, Mich.	58	58	92	462	—	7.2	355	5,597	1.1	6.9	—	622	38	—[e]	—	—	—	22.68
4. Jeffersontown, Ky.	—	—	90	—	—	7.0	—	—	0.6	—	—	—	—	—	—	—	—	132.07
5. South Bend, Ind.	—	—	91	—	—	—	390	—	1.3	6.6	—	—	—	—[f]	—	—	—	17.01
6. Toledo, Ohio	—	—	79	—	—	—	—	—	—	—	—	—	—	—[i]	—	—	—	—

[a] Supernatant. [b] Drying beds and lagoons used. [c] Only 31.8 mgd given secondary treatment. [d] Ranges from 117 to 118,000 during months chlorine is used. [e] Drying beds and vacuum filters used. [f] About 80% of wet sludge trucked away; 20% to beds. [g] 1950 population. [h] Does not include detention in nitrification tank (Krause process). [i] Drying bed and marsh area used.

TABLE II.—Operating Results from Five Primary and Two Chemical Treatment Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Eff. of Treat. (%)	
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent			
										BOD	SS	BOD	SS	BOD	SS
1. Cincinnati, Ohio[a]	12/59	120,000	11.9	—	—	100	—	—	—	190	262	118	81	38	69
2. EBMUD (Oakland, Calif.)	6/59	635,000	60.8	152.9	46.0	96	—	—	—	332	262	203	88	29	66
3. Kenosha, Wis.	12/59	66,000	13.8	29.0	6.9	209	60	—	—	90	139	58	62	36	55
4. Middlesex Co., N. J.[c]	12/59	—	37.3	—	—	—	—	—	—	449	316	364	102	19	68
5. New Britain, Conn.[c]	3/60	73,726[b]	13.1	16.0	9.6	—	—	—	—	206	236	78	70	62	70
6. Racine, Wis.	12/59	88,000	17.8	32.9	9.1	202	57	71	42	138	191	88	80	36	58
7. Winnipeg, Man.	12/59	432,900	39.8	—	—	92	60	—	—	281	305	159	119	44	59

Treatment Plant	Grit Removed (cu ft/mil gal)	Primary Sedimentation				Disinfection	
		Surface Overflow Rate (gpd/sq ft)	Raw Sludge			Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
			Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)		
1. Cincinnati, Ohio[a]	1.2	—	380	1,690	7.1	—	—
2. EBMUD (Oakland, Calif.)	0.3	—	437	1,690	6.2	—	—
3. Kenosha, Wis.	0.8	—	130	800	9.9	—	—
4. Middlesex Co., N. J.[c]	—	—	8,000	3,000	0.6	54	—[f]
5. New Britain, Conn.	2.5	2,910	2,240	—	—	—	—
6. Racine, Wis.	—	942	221	1,010	7.2	—	—
7. Winnipeg, Man.	1.5	—	232	1,395	9.6	—	—

Treatment Plant	Sludge Digestion								Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Supernatant		Dry Yield (psf/hr)	$FeCl_2$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
							Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)					
1. Cincinnati, Ohio[a]	—	—	—	—	—	—	—	—	1.8	5.4	—	31	—
2. EBMUD (Oakland, Calif.)	127	70	—	169	3,170	7.2	437	26,000	—[e]	—	—	—	—
3. Kenosha, Wis.	81	60	91	—	—	7.0	103	710	—[d]	—	—	—	18.50
4. Middlesex Co., N. J.[c]	—	—	—	—	—	—	—	—	—[g]	—	—	—	—
5. New Britain, Conn.[c]	—	—	—	—	—	—	—	—	11.8	1.1	—[i]	32	30.37
6. Racine, Wis.	76[j]	—	94	—	—	7.1	—	—	—[d]	—	—	—	20.70
7. Winnipeg, Man.	—	—	—	—	—	—	—	—	—[k]	2.3	9.7	30	15.50

Treatment Plant	Sludge Digestion — Gas				
	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)
1. Cincinnati, Ohio[a]	1.0	8.7	40	—	36
2. EBMUD (Oakland, Calif.)	1.2	8.3	22	586	36
3. Kenosha, Wis.	0.6	5.3	93	—	—
4. Middlesex Co., N. J.[c]	—	—	—	—	—
5. New Britain, Conn.[c]	—	—	—	—	—
6. Racine, Wis.	0.7	6.4	69	—	—
7. Winnipeg, Man.	0.8	8.0	38	—	34

[a] Little Miami Works. [b] Supernatant. [c] Ocean disposal. [d] Drying beds used. [e] Chemical treatment plant. [f] 96% of samples contained less than 0.2 coliform org./ml. [g] Sludge thickened, stored, and barged to sea. [h] 1950 population. [i] Wet "Prestoline" used. [j] Two-stage digestion; value is for primary tanks. [k] Only 25% of sludge to filters; remainder to lagoons

culties have made it difficult to form any conclusions.

Based on work done at California's East Bay Municipal Utility District, tiles coated with lead acetate have been placed about the plant in the hope that the degree of darkening will uncover the main trouble spots. Calibration of the darkened tile is still a matter of experimentation.

Operations

About half of the thirty-odd employees of the South Bend treatment works have been qualified under the Indiana voluntary certification program and 13 of the staff at Racine hold Wisconsin certificates in the various classifications.

• Operating data from 13 treatment plants appear in Tables I and II. Data in Table I are from activated sludge plants and data in Table II are from primary and chemical treatment plants. Insofar as possible the units of expression used in the tables are those contained in the Federation's Manual of Practice No. 6 which was first published in the May 1958 issue of *Sewage and Industrial Wastes* and is now available as a separate reprint.

Public Relations

Visitors to the Kenosha treatment plant now are handed a manual prepared by the plant staff which permits them to read about the plant units as they look at them.

Safety

California's EBMUD last lost-time accident occurred on May 25, 1953 (as of June 1959), and Fort Wayne ended 1958 with a record of 1,881 days without a lost-time mishap.

Sludge Handling

Looking to the future, Fort Wayne has contracted for the construction of 68 acres of shallow sludge lagoons on a newly acquired 200-acre site 2½ miles downstream from the plant. The contract amount was $230,000, and it is hoped the new facilities will take care of the problem of digested sludge disposal for at least 50 years.

• Work has started on the construction of a 1,000-gal experimental digester at the EBMUD plant. The unit will be similar to the existing plant tanks. When completed, it will be used to study the effects on digestion of loading rate, temperature, cannery wastes, and ground garbage.

Stabilization Ponds

Some experiments were carried out at Winnipeg to see how much the BOD of primary effluent might be reduced by passing it through a lagoon system. Settled sewage was pumped daily into one lagoon and allowed to overflow into a second unit over a 24-hr period. A reduction of BOD was noted, but after a month's operation there were difficulties with Daphnia. To eliminate that problem, the lagoons were drained, rested, and refilled. Good results were obtained from the end of August to the middle of October with loadings of 200 persons per day per acre. In 1960, additional field trials will be carried on in a series of four ponds.

Attention operators! It will be appreciated if copies of the annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: Water Pollution Control Federation, 4435 Wisconsin Ave., Washington 16, D. C.

THE PRIMARY SEDIMENTATION TANK—CONTROL CENTER OF THE TREATMENT PLANT *

By Donald M. Pierce

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Management of a primary sedimentation tank is closely related in many ways with the operation of other plant facilities. No other single unit in the plant provides as much opportunity for detection of conditions, either normal or abnormal, which affect the performance of other plant units. By early detection of unusual characteristics of the raw sewage entering the sedimentation tank, the operator may frequently adjust his normal methods of management of this facility so that harmful and deleterious effects on the subsequent plant units may be minimized. By prompt adjustments in plant controls, protection can often be provided to the sludge digestion process and the processes of biological treatment, such as activated sludge or trickling filters, which are influenced directly by the quality of material leaving the settling tanks.

Establishing Loadings and Performance Ranges

It is generally accepted by operators and design engineers that the composition of sewage, even under normal conditions, varies so widely from plant to plant that a precise determination of its behavior, when subjected to treatment, is impossible. It is universally recognized that each operator must determine for himself over a significant period of time the characteristics which predominate in the raw sewage under normal conditions. He must determine further which of the plant units to depend on for the removal of certain constituents and for their conversion into more stable products. Certainly it is equally important and frequently more significant to become familiar with the quantity and concentration of abnormal or unusual constituents which may appear from time to time.

The wise and conscientious operator, given the time and the proper tools, will become thoroughly familiar with the limitations of plant facilities to cope with unusual conditions arising from unusual volumes or characteristics of the raw sewage or unusual operating conditions affecting one or more interdependent plant units. He will use the primary sedimentation tank as his main detection center. Here he will observe, as frequently as may be appropriate, the physical characteristics of the waste and its behavior as it passes through the settling tank. He will watch for changes in its physical appearance associated with certain industrial wastes, stale or septic sewage, unusual quantities of storm water, large quantities of material flushed from a combined sewer system, and other materials which may have a deleterious effect on plant efficiency. He will take such measurements as may be necessary to determine the chemical composition of the sewage so that the presence of unusual concentrations and quantities of wastes, both in the raw sewage and in the plant effluent, may be detected and measured. The physical appearance and the chemical constituents in the sludge transferred to the sludge treatment and disposal units likewise will be examined.

It is not enough, however, for the operator only to detect and measure

* Presented at the 16th Sewage Works Operators Short Course; Madison, Wis.; Mar. 31–Apr. 2, 1959.

the concentration and quantity of material entering and leaving the sedimentation tank. He must make corresponding observations on the units which follow it to determine the ability of these units to provide treatment under these conditions, either for short or long periods. In some cases he knows in advance of making these measurements that the effect of these materials will be deleterious. In such cases, he must act promptly to establish the necessary controls to prevent unwarranted disruption of the other plant processes. Very often, however, these effects cannot be predicted in advance. Their evaluation can be determined only on the basis of results from a carefully executed and conceived observation and testing program.

Through observation the operator can develop a set of controls which provide for the most effective utilization of the plant facilities. Although the degree of effectiveness will vary from plant to plant, a few fundamental principles have served as general guides for hundreds of plant operators throughout the country. These may be summarized briefly as follows.

Effective Control of Sedimentation Tanks

Equalization of Flow

Usually primary sedimentation tanks are designed to provide detention periods of about two hours at design average rates of flow and to have length, depth, and width ratios such that this volume may be used most effectively for removal of that fraction of the suspended solids which is readily removed by sedimentation. Generally, modern practice calls for the adjustment of these dimensions so that the throughput will not exceed 1,000 gpd/sq ft. It is important that the overflow weirs be of sufficient length to reduce velocities to a level that will not interfere with sedimentation. Equally important are the provision and location of facilities to distribute the incoming sewage equally throughout the cross-section at the entrance to the tank and to provide adequate means for rapidly reducing this velocity so that as much of the tank volume as possible may be used effectively for sedimentation. These features are normally built into the plant.

The operator frequently finds that the provisions for equalizing the flow and providing an environment favorable for sedimentation are not as effective as they should be. He may also find that rates of flow through the plant may require adjustment to provide effective sedimentation. Where sewage is delivered to the tank by pumping, he may be able to adjust the combination of pumps or the pump sequence to reduce the peak loads which significantly reduce effectiveness of sedimentation. Where flows are unequal among several settling tanks, he will almost always find it necessary to provide a means for equalization of the flow by alteration of the piping or perhaps by providing auxiliary means of dividing the flow.

The overflow weirs must be kept level and free from excessive clogging to maintain equal flow.

Scum Removal

Removal of scum, floating garbage, and grease is universally recognized as essential for efficient operation of the settling tanks. A scum barrier or baffle generally is provided somewhere in the flow path between the center of the tank and the effluent weir. A scum trough or rotating pipe is used as a collector into which the scum may be deposited. Excessive skimming will result in too much water being carried over with the scum, while insufficient skimming will permit scum to flow around or under the baffle to join the plant effluent. Ideally, small amounts of scum should be skimmed continuously. Each operating staff will de-

termine by experience the method and frequency best suited to its plant.

Sludge Removal

The majority of primary sedimentation tanks in use today are equipped with mechanical sludge collectors which scrape the settled sludge to a sludge hopper.

Each operator by experience will learn what schedule for sludge removal is most effective for the operation of the settling tank and the sludge digestion tank. He may find it necessary to change the frequency with which the sludge is removed from the bottom of the settling tank and from the sludge hopper to compensate for changes in the quantity and character of the waste. More frequent operation of the mechanical sludge removal equipment, and, correspondingly, more frequent operation of the sludge pumping equipment may be required during periods when an unusual amount of settleable solids are present in the raw waste by reason of certain industrial waste contsituents or when high temperatures of weather and sewage accelerate the rate of decomposition of solids in the settling tanks.

Solids from the sludge hoppers are frequently transferred to a separate sludge hopper by means of a telescoping valve arrangement at the end of a pipe which connects the two hoppers. Whether the sludge is pumped directly from the sludge hopper to the digester or it is first removed to the separate sludge hopper, care must be taken to remove the sludge in a manner and at a rate that will minimize the amount of water transferred to the digester. A good deal of observation and experience normally is required before the operator can establish the rate of removal of sludge which results in virtually complete removal of the solids without producing an overload on the digester. If removal from the sludge hopper is delayed too long, the sludge may become so compacted that it is not possible to remove it effectively.

Regular Maintenance and Repair of Tank and Equipment

All tank surfaces, including weirs and channels, should be maintained regularly to reduce to a practical minimum the accumulation of grease, scum, and other materials of sewage origin which not only become unsightly and produce odors, but also may decrease the settling efficiency and provide an opportunity for accumulated material to be carried out with the effluent. When these materials are discharged to biological treatment units, they may have a deleterious effect on performance.

Routine lubrication, replacement of broken and worn parts, and adjustment of mechanical equipment are essential to the continuous, dependable operation of the settling tank. Lubrication should be performed in accordance with the manufacturer's instructions. Complete inspection and necessary maintenance and replacement on all the equipment and surfaces under water should be conducted at regular intervals, usually not less frequently than once a year.

Normal Operation of Sludge Digestion Facilities

It is well established and generally recognized that raw sludge removed from plain sedimentation tanks contains a high water content which is difficult to separate from the sludge, that it is highly putrescible and nonstable, that it has a high oxygen demand, and that it contains large populations of pathogenic organisms. The main objectives of sludge digestion are to alter these characteristics sufficiently to enable rapid dewatering and stabilization of the organic solids so that they may be disposed of safely and without nuisance.

To accomplish these objectives, an environment must be maintained

within the digester that is favorable for the growth and activity of certain groups of organisms capable of stabilizing the complex unstable organic material in the raw sludge, and at the same time produce a gas of desired quality for supporting combustion and providing energy, thereby reducing the cost of plant operation. Under well-stabilized conditions, the bacterial flora developed will consume a large proportion of the carbonaceous and nitrogenous compounds, in turn producing complex chemical compounds known as enzymes. These enzymes in turn liquify the solids for utilization by bacteria and other microorganisms. The activity of these organisms is promoted by the maintenance of a favorable range of temperature, the proper proportion of raw sludge additions to the well-buffered alkaline sludge which has previously undergone digestion, an adequate period of time for the activity to be completed, and the intimate mixing of the tank contents.

Ideally, the raw sludge constituting the food supply should be added in small quantities at a continuous rate to an environment having all of the essential elements outlined above. This raw sludge should be as fresh as possible and should have a low water content. To counteract the effect of a stale, acid sludge requires additional time in the sludge digestion process.

Sludge Mixing

Thorough mixing of the entire contents of the digester should be accomplished to achieve good digestion. It is of primary importance that the raw sludge should be thoroughly seeded with the digesting solids. In many sludge digestion tanks observed by operators to be operating at low efficiencies, it has been found that lack of mixing has resulted in extensive dead areas in the tank occupied by densely compacted sludge with or without grit, extensive scum formations, and islands of poorly digested material. The space occupied by these materials is not usable for effective sludge digestion, and the total efficiency of the tank is correspondingly reduced. Usually a very low quality supernatant and a poorly digested sludge are produced.

Temperature

The temperature most favorable for digestion has been variously estimated by many authors and other investigators to be between 80 and 100°F. It is rather commonly accepted that this range is between about 85 and 95°F for most effective digestion. The rate of digestion is markedly influenced by departures from these temperatures either below or above the range. If the temperature is lowered substantially, the rate of digestion is decreased and longer periods of digestion are required. These longer periods become very substantial as the temperature is lowered appreciably. As the temperature is increased, the mesophilic organisms, which have been found to be the most effective group in the digestion of sludge, become decreasingly active until at temperatures between 105 and 110°F their activity is reduced to a point where they are replaced by another group of organisms, generally found to be less effective for this type of work.

Control of Scum

The formation of scum is a natural phenomenon in any digester. It is composed of materials lighter than water which have risen to the surface and are lifted above it by their own buoyancy. Here they become dry and incapable of settling in the liquid mass. This material may comprise grease and other fatty materials, sticks, leaves, seeds, rags, and sewage solids. The upward movement of gas within the digester aids in the flotation of this material.

Scum reduces the effective volume for sludge digestion in the tank.

These materials contain large quantities of volatile solids and volatile acids which remain unmixed and unstabilized. When these constituents are dispersed throughout the tank or into the supernatant liquor immediately below the scum layer, there may be a serious detrimental effect even to the point of causing the digesting material to revert to the acid stage.

Continual control of the scum layer is essential. Once it has formed to a thickness of several feet, it becomes very difficult to break up, and after its breakup and dispersion, poor quality sludge and supernatant may occur over a long period. The scum layer may be prevented effectively only by good mixing within the digester. This may be accomplished in several ways. When sludge recirculation is practiced, it is important that the contents within and above the zone where the scum layer could form be recirculated frequently. Recently adopted methods of gas recirculation have proved effective as scum control measures.

Interrelationships of Sedimentation Tank and Digester Operation

In many ways the degree of control exercised in the operation of primary sedimentation tanks affects the performance of the sludge digestion tanks. Conversely, a poorly managed digester may have a damaging effect on the efficiency of a sedimentation tank. The conditions which result in these deleterious effects in either direction include the following categories with which many operators have had experience.

Industrial Wastes

Many types of industrial wastes have a bad effect on sludge digestion. Each operator should become thoroughly familiar with their characterties so that he may know in advance the nature and extent of the effects that may be exerted on the sludge digestion process. With this in mind, he will look for the presence of certain industrial wastes as they enter the sedimentation tank and as they are transferred in the sludge to the digester.

In some cases, these wastes are of such a nature that they should never be permitted to be discharged to the digester, even though they may not have been detected until after substantial quantities have entered the sedimentation unit. In some instances, also, they should not be permitted to reach the biological treatment units by reason of their extremely damaging effect on these processes. In such cases, the operator must find a means of providing special treatment to these wastes before discharge to the stream. He may find it necessary to discharge them into a temporary lagoon or an appropriate holding tank.

1. Explosive and flammable substances. These substances should never be discharged to the sewer system. Examples are dry cleaning fluids, chemical solvents, and gasoline. In the sewer system and sedimentation unit they may create explosions or fires. These materials are readily detected in the sedimentation tanks. They should not be discharged to any of the treatment units or digesters if present in substantial quantities. The materials should be skimmed off or discharged to a special lagoon.

2. Oil. The presence of oil, even in small quantities, interferes with sedimentation and exerts a high oxygen demand on biological treatment processes. In addition it makes maintenance of tank surfaces extremely difficult and acts as a clogging agent in air diffusion systems for activated sludge and provides a deleterious film on trickling filters.

Oil discharged to sludge digestion tanks floats on the surface where it occupies otherwise valuable space needed for sludge digestion, depreciates the quality of the supernatant liquor, and, for some types, creates a

serious explosion hazard. A case in point was observed at Alma, Mich., several years ago when large concentrations of oils were observed in the raw sewage over an extended period of time. Maintenance of the surfaces, including walls, weirs, and channels became difficult and the efficiency of sedimentation was greatly impaired. It was suspected that these oils originated in an oil refinery within the city where an interceptor sewer traversed the refinery property. The interceptor was replaced with a welded steel pipe to eliminate infiltration from the heavily saturated ground. This construction eliminated the oil from the system and made it possible to retsore normal operation. Nearly 10 ft of oil was removed from the sludge digestion tank, which virtually had been out of operation for many months.

3. Toxic substances. Certain constituents of industrial wastes are toxic to the biological processes in sludge digestion tanks and in secondary treatment units such as activated sludge and trickling filters. Some of the more common substances of this type include: (*a*) the metal ions, such as copper, chromium, nickel, zinc, and the cyanides of metals, all of which are present in the wastes from metal plating rooms in various concentrations; (*b*) the insecticides and sprays; (*c*) certain chemicals from chemical manufacturing; and (*d*) phenols and plastic resins. The operator of the sewage treatment plant is frequently able to detect the presence of these materials by noting the color of the waste. For example, a waste high in chromium has a yellowish-green hue. Ordinarily, however, these wastes cannot be easily detected except by laboratory determination. By "keeping his ear to the ground" and being familiar with the industries in the community, the operator is usually able to anticipate the discharge of materials of these kinds and can detect them by laboratory analysis.

When large dumps of these materials are discharged to the sewer system, it may be necessary to provide treatment of a special nature to neutralize or reduce their concentration before discharge to the stream. Frequently it is necessary and justifiable to bypass the secondary treatment units and to lagoon or otherwise store the sludge, rather than discharge it to the sludge digestion tank.

In the small village of Richmond, Mich., three separate electroplating industries discharged wastes into the sewer system over a period of years which resulted in serious impairment of the efficiency of the trickling filter and the digester. These wastes contained chromium, copper, cyanide, and nickel. Very high concentrations of copper and nickel were found in the digester on three separate occasions when gas production had fallen to nearly zero. At the same time, the zoogleal film on the filter was completely stripped off. Following each of these occurrences, the digester was emptied to a lagoon and after operating for a short period in a normal fashion with concurrent restoration of the normal activity on the trickling filter, the industries again began to discharge these wastes into the sewer system with the same result. Currently, this matter is under control by mutual agreement among the industries and a sound industrial waste ordinance.

4. Organic wastes. Organic wastes are usually amenable to treatment in plants employing biological secondary treatment processes, and the solids removed are amenable to treatment in sludge digestion tanks. The main problem arising from the treatment of these industries is the provision of sufficient capacity to provide the necessary treatment, particularly when these wastes are of a seasonal nature. It is the problem of the operator to adjust

the operations for the removal of sludge from the sedimentation tank to the digester in a manner which minimizes the development of septic conditions by reason of early decomposition of these materials. Admission of these wastes to facilities inadequate for their effective treatment may reresult in serious disruption of the biological processes. When unusually large quantities of highly volatile solids are discharged to the digester, the raw food supply may be out of proportion to the amount of well-buffered sludge. This may result in an acid condition which in turn may develop incomplete digestion, inferior quality of sludge gas, and badly depreciated quality of supernatant which in turn imposes a heavy load on the sedimentation units or the biological treatment units to which it is returned. This sets up a cycle which depreciates the effectiveness of all of the plant units.

The operator working from his detection center at the primary settling tank may anticipate these problems by observing and testing for the amount and character of material present and by determining in the light of his knowledge of the capabilities of the plant what their effects may be on the treatment processes. In some cases, it will be apparent that these wastes must be reduced in volume or concentration before they can be admitted to the sewer system. Experience at the village of Caro, Mich., is illustrative of the effect of wastes of this type. Large quantities of wastes from a pea cannery were discharged to the sewer system the first summer after the new plant was built. The plant had not been designed to accommodate this load. The operator was able to detect the presence of these wastes by their characteristic green color which carried through to the trickling filter, the final settling tank, and into the plant effluent. Although he attempted to manage his sludge removal program to discharge the settled solids to the digester as continuously as possible with as little water as he could manage, the digester was seriously overloaded in terms of the proportion of raw sludge to well-digested sludge. A condition of rapid acid regression resulted with production of tremendous quantities of gas with a high hydrogen sulfide content. This gas escaped to the atmosphere around the skirtings of the floating cover. At the same time the trickling filter became loaded with solids, causing a condition of partial pooling and resulting in a general septic condition on the filter surface. The odors from the filter surface and from the digester were extremely obnoxious as indicated by a large number of complaints in the general vicinity of the plant.

At Zeeland, Mich., a chemical company manufacturing biologics discharged a portion of its wastes to the sewer system served by an activated sludge plant. Whenever these wastes were noted by a characteristic color at the plant, the operator observed a sharp drop in efficiency of the activated sludge process and an extremely high chlorine demand in the effluent from the final settling tank. In this case, as at Caro, serious disruption of sludge digestion was experienced after many months of intermittent discharges of various types of organic wastes from this industry. Correction did not develop until the industry reduced very sharply the amount of discharge to the sewer.

At Clare, Mich., a milk-processing plant discharged large quantities of milk wastes to the sewer system. After the new plant had been in operation for about two years, a scum layer about four or five feet in depth developed in the digester, reducing its capacity and developing an extremely strong supernatant which in turn reduced the efficiency of the primary settling tank. This waste was ob-

served daily by the operator by its characteristic milky color.

At one of the automobile manufacturing plants, the sewage treatment plant, designed to serve the sanitary facilities only, has been subjected to intermittent discharges of highly concentrated detergents used in the industrial operations. Although these detergents did not foam, their appearance could be detected by their characteristic color of skim milk. A single large discharge of this material completely stripped the biological growth from the trickling filter thereby reducing its effectiveness for a period of several weeks. The operator now bypasses the trickling filter should the appearance of detergents be noted. In the meantime, effective correction is being developed by adjustment of the industrial operation so that the detergents do not reach the sewer.

Grit

Large quantities of grit resulting from improper operation of the grit removal facilities on a combined sewer system create many operational problems. Increasingly, it is becoming evident that so-called separate sanitary sewer systems are not necessarily free of substantial quantities of grit, particularly where construction of the sewer system is not supervised carefully. Even then, failure of the sewer system may result in the washing in of large quantities of grit. The presence of grit normally can be detected by laboratory testing of the sludge transferred to the digester. A high percentage of inert material, as compared with normal values, will indicate the presence of this material. Grit is difficult to remove from the sedimentation units, and, when removed, interferes with effective operation of the sludge digestion facilities by (*a*) occupying space uselessly and (*b*) obstructing the movement of digester contents either for recirculation purposes or for final disposal.

At Blissfield, Mich., when a new certified operator had operated the plant for a few days, he noted the high percentage of inert material in the raw sludge. Less than 20 per cent of the solids was volatile. Examination of the interceptor and sewer system disclosed a large break in a new trunk sewer in a sandy area. Three feet of sludge had been deposited in the sludge digestion tank in a period of a few weeks after the break was known to have occurred. The presence of the grit made it impossible to move the sludge and the sludge digestion tank had to be emptied.

At another new plant serving a large new subdivision, large quanities of muddy water were noted entering the sewage treatment plant whenever runoff occurred in the area. Although a separate sanitary sewer system was used, it was general practice among the builders to drain the basement areas into the house sewer by merely removing the "cookie" from the sewer. Although the operator was acutely aware of the deleterious effect of these muddy waters on treatment processes, he was unable to obtain correction until a rigidly enforced sewer ordinance had been adopted by the township in which the plant was located. In the meantime it became increasingly difficult to remove the sludge from the settling tank by reason of grit accumulations. Fortunately, no sludge digestion tank was installed at this plant. Rather, the sludge was pumped to a sludge storage tank and hauled to another plant for treatment. It was evident to the operator that, had the sludge been transferred to a digester, great difficulty would have been experienced with movement of sludge with this high content of grit. The settling tank took out little of the clay in the sewage. It was passed on to the trickling filters, which in turn passed on much of it to the sand filters. The clay so completely covered

the sand that the filters' hydraulic capacity and efficiency were drastically reduced. After a few months, it became necessary to replace several inches of this sand. This was repeated three times in one year before the source of the trouble was corrected.

It is clear from these few examples that the operator, by careful observation and by timely testing of the sewage which enters the tank and of the sewage and sludge which leave the tank, has an opportunity to detect unusual constituents usually in time to provide correction before the other plant units are adversely affected. In some cases, of course, even though he is conscious of the unusual condition and has made rather exact determinations of concentration and volume, he is unable to apply correction by reason of matters beyond his control.

Sludge Transfer

Except for the presence of industrial wastes and other materials detrimental to treatment processes, the manner in which sludge is removed from the sedimentation tanks and transferred to the sludge digestion tanks has a greater effect on the operation of these two units than any other single factor. As mentioned earlier, under ideal conditions sludge should be removed continuously from the settling tanks and transferred at low rates to the digester. If the solids are permitted to remain in the settling tank, even for a few hours under certain conditions, they may become septic. This condition results in lowered percentage removal of the solids and BOD because some of the solids are buoyed to the surface by the gas produced by their decomposition. This septic sludge, when pumped to the digester, imposes an extra burden on the unit.

Continuous removal of sludge to the digester provides a constant food supply for the organisms doing the work. Large quantities of raw sludge transferred to the digester in short periods causes a feast-or-famine condition. This overload manifests itself by producing a supernatant quality which contains more solids, a higher oxygen demand, and a higher volatile solids content. Return of this material to the settling tank or other plant units sets up a cycle which lowers the effectiveness of the units involved and ultimately degrades the plant effluent.

When one considers the opportunity for detection of unusual conditions in the raw sewage arriving at the plant by alert operation of the primary sedimentation tank, it becomes obvious, as it is to most operators, that this is the key unit and control center for the entire sewage treatment plant.

FLOODING OF HOMES WITH SEWAGE*

By W. N. Wells

Sewage Treatment Engineer, San Antonio, Tex.

Nothing is more disturbing to a citizen than the flooding of his home with raw sewage, and nothing can cause the sewer maintenance superintendent's telephone to ring louder and longer nor his ears to burn brighter than the frantic cries of a housewife as the evil flood spreads from the bathroom to the hall over her expensive wall-to-wall carpeting.

The stoppage of a service line which prevents the normal use of fixtures is an inconvenience usually solved by a

* Presented at the Annual Short School for Water and Sewage Works Operators; College Station, Tex.; Feb. 29–Mar. 4, 1960.

telephone call to the nearest plumber. But the flooding and overflow of the fixtures is another matter. There is something inherently repugnant about having sewage from another source flood his home; it stirs primitive emotions in the average citizen. Chastisement of the maintenance superintendent and a lawsuit against the city are minor items which pass through his mind.

Those in charge of sewer maintenance in San Antonio have had their share of experiences. As soon as a cloud appeared in the sky, the department could expect a call from Mrs. Adams of High Street. An overloaded line in her alley always caused trouble when it rained, and she wanted someone there to rod it out before any trouble developed.

Mr. and Mrs. Brown and their three children pulled into their driveway after attending church services one bright Sunday morning. Everything seemed normal until they reached the front porch. At that point their noses told them something was wrong, and when they opened the door, they were met by a flood of sewage. Investigation later showed that sewage had overflowed from a drain into which condensate from the air conditioning system was wasted. This was a $32,000 house, and the Browns had insurance coverage which paid for replacing all flooring in the house.

Mr. and Mrs. Cross shared an experience almost exactly like the Browns except that they had been out of town for several days, and the sewage was a bit riper. The Crosses also had insurance to cover the damage, so out came the flooring.

In recent years, despite some rather lurid threats, none of the floodings has resulted in damage suits. The city's attorneys have maintained that operation of the sewerage system is a governmental function and thus not subject to civil suits. Regardless of the legal aspects, a home owner purchases his home in good faith and with little technical knowledge of sewers and their operation. He is certainly entitled to trouble-free operation of this facility.

Solving the Problem

A closer look at the problem seems warranted. The problem, it is said, is "Simple." "The sewer stops up with trash and backs up into the house." *Not so!!* There are hundreds of stoppages each year, and only a relatively few result in house flooding. In most cases, the sewer simply relieves itself

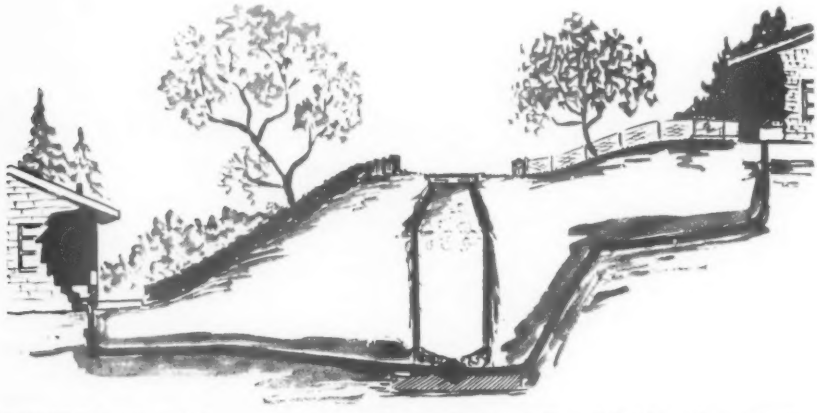

FIGURE 1.—A typical sewer installation in an alley in a hilly subdivision where flooding will occur in the lower house each time the alley sewer is surcharged.

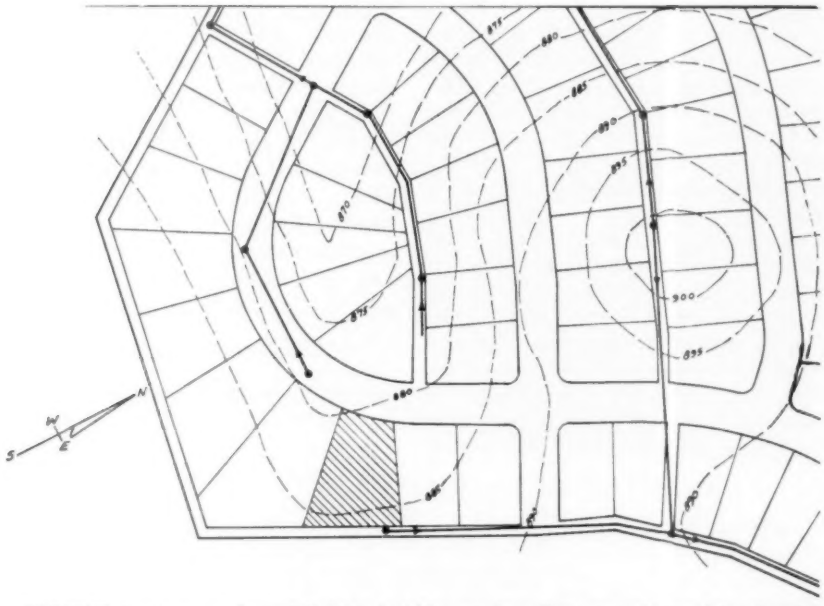

FIGURE 2.—Layout of a subdivision in hilly terrain. Care must be used in planning sewers to prevent flooding. The house on the shaded lot flooded when connected to the sewer east of it. Flooding was corrected by a connection to the sewer west of the lot.

at the nearest manhole until the stoppage is corrected—a little mess in the streets, perhaps, but not inside a home. For flooding to occur, the pressure or head in the sewer must become greater than the head in the service line and the house fixtures. This condition is most frequently met when the opening of the nearest upstream manhole is on the same elevation or higher than the house fixtures. Under these circumstances, a stoppage or a surcharge of the sewer caused by storm water will cause flooding of the house.

There are a number of trends in house and sewer construction which have accentuated the problem in recent years. Subdivisions are being developed in hilly country with streets and alleys curving around the hills. If a sewer is laid in a hillside alley, the house on the high side of the alley will be safe, but there is a good chance that the house on the low side will be subject to flooding (Figure 1). Anything which brings the house fixtures to the same level as or below the upstream manhole cover increases the danger of flooding. Slab foundations with the house floors at ground elevation have increased the danger of flooding. Shower drains and air-conditioning drains at floor elevation have increased the problem. The use of bolt-down type manhole covers has not helped the situation any. Moreover, it is believed that when the sewer becomes surcharged, the manhole covers should open and allow the sewer to relieve itself in the street. It is not desirable to have sewage running in the street every time it rains, but the street is a better place for it to run than inside a house.

The most desirable correction of flooding begins with proper sewer design. Sewers should be designed in a manner which puts the manhole cover below the elevation of house fixtures. When the topography of the lot does

not permit this, another sewer should be laid along the low side of the lot. True, this is an added expense to the developer which is passed along to the homeowner, but it is really the only satisfactory solution to the problem. With the problem in mind, the architect might alter his design to bring the fixtures above a safe elevation or the elevation of the lot might be raised enough to prevent flooding.

In an existing situation, re-laying the sewer and reconnecting service lines may be quite expensive. A check valve may be installed in the service line, but this means that the fixtures cannot be used anytime the sewer is surcharged, and check valves have been known to fail. A relief valve may be installed in the service line. This merely consists of a joint or two of 4-in. pipe tapped into the top of the service line just outside the house and terminating at the surface of the ground. This works well and will prevent flooding of the house. But it will not prevent flooding of the yard, and the homeowner is reluctant to accept this as a permanent solution.

Conclusion

Sewers should be designed with the problem of flooding in mind (Figure 2).

TIPS AND QUIPS

Havoc *

In February, several employees were engaged in salvaging bronze plates from three fine screens at the South Yonkers, N. Y., sewage treatment plant. One of the men noticed an odor strange to this plant, and all of the men climbed out of the screen pits to the main floor level. Almost immediately an explosion took place.

Eight employees were taken to the hospital; three were released shortly, but two weeks later, two men were still undergoing treatment.

The blast blew out 3 large roller doors, 16 skylights, and nearly 200 concrete roof slabs fell or hung precariously from the framing.

A preliminary report by the police points to the probability that a flammable material was discharged to the sewer. The source of ignition was undetermined.

On the day of the South Yonkers explosion, an operator at the Gloversville, N. Y., plant was pronounced dead on arrival at the hospital from what the coroner ruled was inhalation of "sewer gas."

In a later recounting of the events which preceded the tragedy, it was reported that the victim entered the sludge pump house at 11:30 AM to operate the controls. After entering the building, he was seen twice standing on the steps. At 11:50, another employee entered the building and found the victim on the floor. The other employee, by the way, was nearly overcome while attempting to drag the victim outside.

The sludge pump house is approximately 12 ft square built on top of a wet well 15 ft deep. Raw sludge flows by gravity to the wet well; a bar rack is located at the influent pipe. Normal procedure is to enter the building to operate the pumps and periodically clean the rack. Natural ventilation consisted of two windows, a door, and an 8-in. roof vent. Odors

* From May 1960 *Gas Vent*, the newsletter of the New York Sewage and Industrial Wastes Association.

were usually present and forestalled any extended stay in the room.

In a later visit to the room, W. G. Wilkie, District Engineer of the state health department, reported that a 25-¢ piece held 20-in. above the floor turned black in 4 min.

Digester Seeding *

One of the largest digester-seeding jobs took place recently when 120,000 cu ft of heated sludge was transferred from New York's Hunt's Point plant to the new 75-mgd South Yonkers plant of the Westchester County Department of Public Works. The transfer was made by sludge boat. Sludge was placed in the new digesters on April 7 and 8, and burnable gas was being produced in sizeable quantities by April 10.

The digesters and a storage tank were purged with 4 tons of compressed carbon dioxide prior to filling them with sludge.

Wisconsin Sewage Treatment Plant Supervisor Honored

John Wallendal, Supervisor of the Waupun sewage treatment plant, was awarded the George F. Bernauer Memorial Award at the recent joint meeting of the Conference of Wisconsin Sewage Works Operators and the Central States Sewage and Industrial Wastes Association. The Award, first to be presented in Wisconsin, is given "for exceptional contribution in the field of wastewater technology."

The George F. Bernauer Memorial Award is given for successful plant performance as indicated by operational records, and/or; successful solution of important or complicated operational problems, and/or; outstanding

George F. Bernauer Memorial Award.

contributions in wastewater technology as related to problems in the state of Wisconsin. The principal purpose of the Award is to stimulate improvements in the field of wastewater treatment. It is named for George F. Bernauer, who was well known as public health engineer for the Wisconsin State Board of Health throughout the central states area.

Filter Flooding †

Lowell Halderman, chief operator of the Urbana, Ohio, treatment plant, describes a way to flood a trickling filter not equipped with valves on the effluent line.

An inner tube is inflated, weighted to overcome buoyancy, and placed against the wall. Then an aluminum gate of the proper size is held against the tube until sufficient water pressure has developed to seal the plate against the tube, and the tube against the wall.

It hurts more to have a belief pulled than to have a tooth pulled, and no intellectual novocaine is available.

ELMER DAVIS

* From May 1960 *Gas Vent*, the newsletter of the New York Sewage and Industrial Wastes Association.

† From *Buckeye Sludge*, Spring 1960.

Federation Affairs

THIRTY-THIRD ANNUAL MEETING PREVIEW

Sheraton Hotel, Philadelphia, Pa.

Technical Sessions and Exhibits—Convention Hall

October 2–6, 1960

★

HOST ASSOCIATION—PENNSYLVANIA WATER POLLUTION CONTROL ASSOCIATION

★

THE OFFICIAL PROGRAM

SUNDAY, OCTOBER 2

Afternoon

Early Registration

Ladies only: Sheraton Hotel
Men only: Convention Hall

MONDAY, OCTOBER 3

Morning

Registration

Ladies only: Sheraton Hotel
Men only: Convention Hall

Inspection of Exhibits—Convention Hall

Call to Order

President Mark D. Hollis

Invocation

Welcome to Philadelphia—The Honorable Richardson Dilworth, Mayor of Philadelphia

Reports of Federation Officers

Comprehensive Survey of the Water Resources of the Delaware River Basin

Col. T. H. Setliffe, District Engineer, U. S. Army Engineer District, Philadelphia, Pa.

Afternoon

Where Do the States Stand in Water Pollution Control?
Curtiss M. Everts, Director, Division of Sanitation and Engineering, Oregon State Board of Health, Portland, Ore.

Where Does Research Stand in Water Pollution Control?
Harry G. Hanson, Director, Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio

Where Does Industry Stand in Water Pollution Control?
A. J. Steffen, Director of Sanitary Engineering, Wilson and Company, Inc., Chicago, Ill., and Chairman, National Technical Task Committee on Industrial Wastes

TUESDAY, OCTOBER 4

Morning—Concurrent Sessions

SESSION A—PUBLIC RELATIONS

Why Public Relations is a Day-to-Day Job
C. F. Wertz, Director, Department of Water and Sewers, Miami, Fla., and President, American Water Works Association

Public Relations—THOUGHTS plus ACTION equals RESULTS
J. E. Meers, Superintendent, Sanitary District of Bloom Township, Chicago Heights, Ill.

Better Understanding of Water Pollution—A Challenge
Robert F. Orth, Senior Vice-President, Johns-Manville Corporation, and Chairman, Public Relations Committee, Water and Sewage Works Manufacturers Association

Public Relations—How to Use It to Accomplish Our Goals
Ted Sperling, Director of Public Information, Metropolitan St. Louis Sewer District, St. Louis, Mo.

SESSION B—MAINTENANCE FORUMS

PLANT MAINTENANCE PANEL—Leader, Joseph B. Hanlon, Superintendent, Sewage Treatment Plants, Metropolitan District Commission, Boston, Mass.

Mechanical Maintenance—Large and Small Treatment Plants
R. C. Thayer, Director of Operations, Hampton Roads Sanitary District Commission, Norfolk, Va.

Operating Experiences of Whitemarsh Township's Treatment Plant and Refuse Incinerator
Bertram B. Reilly, Manager, Research and Development Department, Dravo Corporation, Pittsburgh, Pa.

Operation and Maintenance of Incinerator Furnaces
Ray D. Leary, Chief Engineer and General Manager, Sewerage Commission, Milwaukee, Wis.

SEWER MAINTENANCE PANEL—Leader, Earl R. Howard, Superintendent, Bureau of Public Works, Hartford, Conn.

Recent Investigations of Overflows from Combined Sewers in Washington, D. C.
George J. Moorehead, Chief, Planning Branch, Department of Sanitary Engineering, Washington, D. C.

Discussion
C. Frank Johnson, Metcalf and Eddy, Boston, Mass.

Repair of the Chelsea Sewer

Paul F. Henderson, Senior Civil Engineer, Construction Division, Metropolitan District Commission, Boston, Mass.

Sewer and Catch-Basin Cleaning in the Hartford Metropolitan District

Edward A. Kowsz, Assistant Operating Engineer, Bureau of Public Works, Metropolitan District, Hartford, Conn.

SESSION C—INDUSTRIAL WASTE SESSION

Control and Treatment of Oily Wastes

Mike Madarasz, Plant Engineering Office, Ford Motor Company, Detroit, Mich.

Waste Control at the Hanford Plutonium Production Plant

R. F. Foster, R. L. Junkins, and C. E. Linderoth, General Electric Company, Richland, Wash.

Systems for Handling Wastes from Manufacture of Orlon Acrylic Fiber

E. Folger Taylor, Frank T. Bordurtha, Jr., Robert F. Rocheleau, and George C. Gross, E. I. du Pont de Nemours and Company, Waynesboro, Va.

Discussion

James I. Otis, Virginia Water Pollution Control Board, Richmond, Va.

Can Industry Grow in the Face of An Active Pollution Abatement Program?

Walter A. Lyon, Director, Division of Sanitary Engineering, Pennsylvania Department of Health, Harrisburg, Pa.

Noon

FEDERATION LUNCHEON

Address

The Honorable Arthur S. Flemming, the Secretary of Health, Education, and Welfare

Afternoon

CONCURRENT INSPECTION TRIPS

Inspection Trip A

Atlantic Refining Company's Waste Treatment Facilities

Inspection Trip B

Philadelphia's Northeast Sewage Treatment Works

Inspection Trip C

Whitemarsh Township's Sewage Treatment Plant and Refuse Incinerator

RESEARCH SYMPOSIUM

Ammonia Nitrogen and the Anaerobic Environment

O. E. Albertson, Development Department, Dorr-Oliver Inc., Stamford, Conn.

The Effects of Copper on the Activated Sludge Process of Sewage Treatment

W. Allan Moore, G. N. McDermott, Mildred A. Post, J. W. Mandia, and M. B. Ettinger, Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio

Quantitative and Qualitative Shock Loading of Activated Sludge Systems

Anthony F. Gaudy, Jr. and Richard S. Engelbrecht, Assistant Professor and Associate Professor, Sanitary Engineering Department, University of Illinois, Urbana, Ill.

The Effect of Physical and Chemical Agents on Oxygen Absorption

W. W. Eckenfelder, Jr. and Edwin Barnhart, Associate Professor and Research Assistant, Civil Engineering Department, Manhattan College, New York, N. Y.

WEDNESDAY, OCTOBER 5

Breakfast—Laboratory Scientists

Determination of Radioactive Substances

Lloyd R. Setter, A. S. Goldin, and H. L. Krieger, Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio

Morning—Concurrent Sessions

SESSION A—SMALL PLANT DESIGN AND OPERATION

The Trafalgar Township Sewage Treatment Plant

John G. Powell, Director and Vice-President, Gore and Storrie, Ltd., Toronto, Ont.

Small Plants in Metropolitan Seattle

Frank J. Kersnar, Metropolitan Engineers, Seattle, Wash.

Observations on Small Sewage Treatment Plant Designs

LeRoy W. Van Kleeck, Bowe, Albertson and Associates, West Hartford, Conn.

Design of Small Sewage Treatment Plants

Warren E. Hoxworth, Hoxworth, Behnke and Girard Associates, Haddonfield, N. J.

SESSION B—INDUSTRIAL WASTES—INDUSTRY DAY

A Cooperative Program for Pollution Abatement in the Kanawha River

Part I

Bern Wright, Secretary, State Water Resources Commission of West Virginia, Charleston, W. Va.

Part II

A. C. Hyde, Production Supervisor, E. I. du Pont de Nemours and Company, Charleston, W. Va.

A Unique Treatment and Disposal System for Combined Wastes at Harriman, Tenn.

Julian R. Fleming, Director, Division of Sanitary Engineering, Tennessee Department of Public Health, Nashville, Tenn.

Fair Sewage Service Charges for Industrial Wastes

Kenneth V. Hill, Partner, Greely and Hansen, Chicago, Ill.

Discussion

Ralph C. Peterson, Procter and Gamble, Cincinnati, Ohio

Cannon Mills Solves its Textile Wastes Problem

John L. Brown, Jr., Sanitary Engineer, Cannon Mills Company, Kannapolis, N. C.

Noon

INDUSTRY LUNCHEON

Enlightened Self-Interest: Guideline to Water Conservation

Robert G. Dunlop, President, Sun Oil Company, Philadelphia, Pa.

Afternoon—Concurrent Sessions

SESSION A—MICROBIOLOGY AND BIOLOGICAL TREATMENT

The Anaerobic Contact Process

Edwin B. Fall, Jr. and L. S. Kraus, Chemist and Manager, Greater Peoria Sanitary District, Peoria, Ill.

Discussion

James B. Coulter and M. B. Ettinger, Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio

Microbiological Aspects of Sewage Lagoon Operation

C. D. Parker, Lucey R. Alford, H. L. Jones, and A. D. Beer, Research Laboratories, Melbourne and Metropolitan Board of Works, Melbourne, Victoria, Australia

SESSION B—WASTEWATER COLLECTION AND TREATMENT

Pittsburgh's Sewage Disposal Project—Construction and Operation

John F. Laboon, Executive Director, Allegheny County Sanitary Authority, Pittsburgh, Pa.

Effectiveness of the Interception of Sewage—Storm Water Mixtures

W. G. Shifrin and W. W. Horner, Horner and Shifrin, St. Louis, Mo.

Gamma Radiation Control of Raw Sludge Pumping

Charles O. Badgett, Process Industries Manager, Industrial Nucleonics Corporation, Columbus, Ohio

Criteria for Evaluating Deep Trickling Filter Performance

F. J. Burgess, C. M. Gilmour, Fred Merryfield, and J. K. Carswell, Oregon State College, Corvallis, Ore.

SESSION C—INDUSTRIAL WASTES—INDUSTRY DAY

Manufacturing Chemists' Association's Research Project on Taste and Odors

Robert A. Baker, Senior Staff Engineer, Franklin Institute, Philadelphia, Pa.

Turbine Mixer Aeration in an Activated Sludge Plant Treating Pharmaceutical Wastes

Wm. G. Barker, R. H. Otto, D. Schwarz, and B. C. Tjarksen; Chemical Engineer, Development Department; Research Microbiologist, Research Department; Chemical Engineer, Engineering Department; and Chemical Engineer, Chemical Manufacturing Department; all of Abbott Laboratories, North Chicago, Ill.

Industry-ORSANCO Cooperation in Pollution Control

Nelson J. Ehlers, Columbia-Southern Chemical Corporation, Pittsburgh, Pa.; Richard S. Rhodes, Koppers Company, Pittsburgh, Pa.; and O. C. Thompson, Union Carbide Chemicals Company, South Charleston, W. Va.

Discussion
Robert Horton, Assistant Director, ORSANCO, Cincinnati, Ohio

Experience in Dephenolization of By-product—Coke Ammoniacal Liquor
W. E. Carbone, Wilputte Coke Oven Division, Allied Chemical Corporation, New York, N. Y.

Evening

ANNUAL FEDERATION AWARDS DINNER AND DANCE

THURSDAY, OCTOBER 6

Morning—Concurrent Sessions

SESSION A—OPERATORS' FORUM

Equipment Maintenance by Plant and Outside Personnel
E. Huntley Delano, Superintendent, Sewage Treatment Plant, Grand Rapids, Mich.

Disposal of Screenings and Scum
George W. Martin, Superintendent, Green Bay Metropolitan Sewer District, Green Bay, Wis.

The Repair and Replacement Parts System
A. C. Bryan, Superintendent, Sewage Treatment Plants, Houston, Tex.

Flow Meters, Gas, Liquid, and Air
Anton E. Sparr, Superintendent, Upper Potomac River Commission Waste Treatment Plant, Westernport, Md.

SESSION B—INDUSTRIAL WASTES FORUM—SOLIDS REMOVAL AND SLUDGE DEWATERING

Moderator: Harry W. Gehm, Technical Advisor, National Council for Stream Improvement, Inc., New York, N. Y.

Sludge Handling in the Steel Industry
Richard D. Hoak, Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Solving the Sludge Problem in the Pulp and Paper Industry
Russell O. Blosser, National Council for Stream Improvement, Inc., Kalamazoo, Mich.

Atlantic Refining's Approach to Sludge Disposal
R. G. Merman and P. J. Ferrall, Atlantic Refining Company, Philadelphia, Pa.

New Concepts of Flocculation in Liquid-Solids Separation
S. J. Mogelnicki and C. P. Priesing, Sanitary Engineer and Resident Chemist, Dow Chemical Company, Midland, Mich.

TECHNICAL PROGRAM COMMENTS

Program Committee Chairman George E. Symons and his group have spared no effort in putting together an especially worthy and pertinent technical program.

This year it is larger than ever—two additional sessions have been added, making 13 altogether. Over 50 speakers are in the throes of making last-minute changes to their papers and

convention-goers in general are readying questions for the discussion periods.

Industrial wastes are in for the closest scrutiny they have ever received. As a matter of fact, Wednesday, October 5, has been designated INDUSTRY DAY and a top industry spokesman, Robert G. Dunlop, president of the Sun Oil Company, will speak at the INDUSTRY DAY luncheon.

The annual Federation luncheon will feature an important address by the Honorable Arthur S. Flemming, the Secretary of Health, Education, and Welfare. Secretary Flemming's espousal of the Administration's water pollution abatement policies reflects the serious consideration water resources problems are receiving at the very highest levels of government.

All technical sessions will be held in Convention Hall; the luncheons, however, will be at the Sheraton.

OTHER FUNCTIONS

Entertainment on Monday evening will feature a bright musical revue that promises to start toes tapping. But don't blame us for tired feet.

Tuesday evening is an open night and the Local Host Committee stands ready to help you form your personal plans. If you want suggestions, these are the people to see. A good bet is that Philadelphia's five legitimate theaters probably will be busy with Broadway-bound productions.

The Federation Awards Banquet and Dance will be held on Wednesday evening in the Sheraton Ballroom. Last year close to 750 gathered together for this social high point of Federation Week. At the banquet, Federation awards and honors will be presented and new officers formally introduced. Dress is optional.

In addition to the official functions, there will be a joint breakfast meeting of the state water pollution control administrators and the Conference of State Sanitary Engineers. This is scheduled for Wednesday.

Independence Hall is called the "Nation's No. 1 Shrine" and it is just one of the many famous sites about which Philadelphians can justly boast.

A partial listing would include: Betsy Ross House, Franklin's grave in Christ Church burial ground, Carpenters' Hall, Second Bank of the U. S., Atwater Kent Museum, Elfreth's Alley, Fels Planetarium, Franklin Institute, Pennsylvania Academy of Fine Arts, and the Academy of Natural Sciences.

A "get acquainted packet," describing Philadelphia's facilities and attractions, is available for the asking. Write for "Packet S," Mayor's Office for Information and Complaints, Room 121, City Hall, Philadelphia, Pa.

LADIES' ENTERTAINMENT

Steeped in the Nation's history and busily occupied with things present, Philadelphia has those ingredients which make it unique. In the midst of plenty, the Ladies' Entertainment Committee has planned a nonpareil three-day program. Only the highlights are given here.

On Monday afternoon there will be a tour of historical Philadelphia which will take in Independence Hall, Christ Church, Betsy Ross House, colonial houses, Old Swedes' Church, Carpenters' Hall, and Elfreth's Alley.

A trip to New Hope in beautiful Bucks County will occupy most of Tuesday. There will be a luncheon stop at the Washington's Crossing Inn which is located on the Delaware River adjacent to the point where General Washington crossed the river to win

the battle of Trenton. New Hope itself is filled with arts and crafts shops.

Brunch at the Sheraton on Wednesday will feature a speaker who will have something to say to women, on a subject of interest to women. The remainder of the day will be available for side trips and shopping.

TECHNICAL INSPECTIONS

Tuesday afternoon has been set aside for inspection trips. Those selecting Trip A will visit the waste treatment facilities of the Atlantic Refining Co. in southwest Philadelphia. These facilities represent an investment of almost $7 million. The plant treats an average of 13 mgd of waste flow and storm-water runoff from an area of 200 acres.

Treatment consists of oil and grit separation, pH adjustment, flocculation to remove emulsified oil, and solids dewatering and incineration. Atlantic's treatment plant is one of the largest of its kind.

Trip B will be to the Northeast sewage treatment plant, the largest of Philadelphia's three plants. It serves about 850,000 people and treats an average flow of 150 mgd.

Treatment consists of screenings and grit removal, primary sedimentation, contact stabilization integrated with modified aeration, final sedimentation, and sludge digestion and lagooning.

The new facilities at Whitemarsh Township will be viewed on Trip C. In this northwest suburb is a plant typical of the smaller installations in the Delaware Valley. The treatment works has a design capacity of 2.5 mgd and it contains screenings and grit removal units, primary and secondary sedimentation tanks, two-stage high-rate trickling filters, and sludge dewatering equipment. Unique at Whitemarsh is a refuse incinerator in which dewatered sludge is burned. The incinerator uses plant effluent for cooling purposes.

EXHIBITS

Members of the Water and Sewage Works Manufacturers Association will exhibit their latest products in the spacious quarters of Convention Hall, and the moments spent inspecting the booths will be among the most profitable of Federation week. Exhibits will be open for inspection beginning on Sunday afternoon.

The following companies have engaged exhibit space and are ready to produce the finest technical display of the Federation's history:

Airkem, Inc.
American City Magazine
American Well Works
Armco Drainage & Metal Products, Inc.
B-I-F Industries, Inc.
Bird Machine Company
Burgess-Manning Company, Penn Instruments Division
Ralph B. Carter Company
Centriline Corporation
Chain Belt Company
Chicago Pump Company
Combustion Engineering, Raymond Division
DeZurik Corporation
Dorr-Oliver Inc.
Eimco Corporation, Process Engineers Division
Engineering News-Record Magazine
Fischer & Porter Company
Fisher Scientific Company
Flexible Inc.
Foxboro Company
Gorman-Rupp Company
Hardinge Company, Inc.
Inertol Company, Inc.
Infilco Inc.

Jeffrey Manufacturing Company
Johns-Manville
Keasbey & Mattison Company
Komline-Sanderson Engineering Corporation
Lakeside Engineering Corporation
Link-Belt Company
Lock Joint Pipe Company
Marlow Pumps, Division of Bell & Gossett Company
Nichols Engineering & Research Corporation
Pacific Flush Tank Company
Perry-Austen Manufacturing Company
Public Works Magazine
Robinson Clay Product Company
Rockwell Manufacturing Company
Roots-Connersville Blower, Division of Dresser Industries, Inc.
A. O. Smith Corporation
Smith-Blair, Inc.
Smith & Loveless, Division-Union Tank Car Company Stuart Corporation
Stuart Corporation
Sutorbilt Corporation
Tex-Vit Supply Company, Manufacturing Division
Vapor Recovery Systems Company
W-K-M Division of ACF Industries, Inc.
Walker Process Equipment Inc.
Wallace & Tiernan Inc.
Wastes Engineering Magazine
Water & Sewage Works Magazine
Waukesha Motor Company, Climax Engine Manufacturing Company
Wemco Division of Western Machinery Company
Worthington Corporation
Yeomans Brothers Company

REGISTRATION INFORMATION

This year men will register at Convention Hall and women will register at the Sheraton. A separate registration desk for ladies is needed for convenience's sake since their activities will be centered at the hotel. Tickets for social events, however, will be available only at the Convention Hall desk.

Separate pickup stations also will be maintained for preregistering men and women. Remember—men go to Convention Hall; ladies go to the Sheraton.

Shuttle buses will begin running on Sunday afternoon between the hotel and Convention Hall, and they will be in service for the duration of the meeting. On Sunday, the registration desk will be open from 1 to 5 PM, and Monday-through-Wednesday registration will be from 8:30 AM to 4:30 PM.

Men's registration at $15 includes admission to the technical sessions, the Monday night Theater Party, and the Annual Awards Dinner and Dance on Wednesday evening. Separately, the registration fee (required for admission badges to the technical sessions) is $8 and the Wednesday Dinner and Dance combination is $7.

The ladies' entertainment fee of $15 includes tickets for all the ladies' events as well as the Annual Awards Dinner and Dance. Separately, the tickets for all the ladies' events cost $8 and the Wednesday night Dinner and Dance is $7.

Individual tickets will be sold for the Federation Luncheon on Tuesday, the inspection trips, the Laboratory Scientists' Breakfast, the Industry Day Luncheon, and the Annual Dinner and Dance.

PREREGISTRATION

If you are a speed demon or hate delay, preregistration is for you. There is no fuss or bother; preregistering men will simply step up to the registration desk at Convention Hall and have their badges and tickets handed to them. Ladies will do the same, but at the Sheraton instead of Convention Hall.

Preregistration information was

mailed to all members at the end of July, and, if you have not already done so, there is still time to complete the form, enclose your check, and forward both to the WPCF office, 4435 Wisconsin Ave., Washington, D. C.

Should a change of plans prevent you from attending the meeting, a full refund will be made. Tickets must be picked up a half business day prior to the luncheon or dinner events as the Federation makes guarantees for these functions. If tickets are claimed later, there will be no assurance of a place at these events, but under these circumstances a refund is authorized.

To assure processing of preregistration cards, the completed information together with remittance must be received in the Federation office by Thursday, September 29. Since checks will not be negotiated until after the meeting, there is no need to date them earlier than October 6.

HOTEL ARRANGEMENTS

The Sheraton will be the headquarters hotel, but a generous allocation of rooms has been made by the Benjamin Franklin, the Warwick, the Robert Morris, and the Franklin Motor Inn. This year you will have the opportunity of selecting the hotel you prefer.

Requests for room reservations should be made as soon as possible using the hotel reservation card enclosed with the preconvention flyer.

All reservations must be received in Philadelphia by September 24.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under Chairman Samuel S. Baxter and Vice-Chairmen Samuel I. Zack and Alfred A. Estrada, extends to every member a special invitation to come to Philadelphia.

Serving on the various subcommittees of the Local Arrangements Committee are these hard-working Pennsylvanians:

Hotel and Convention Hall Arrangements: J. J. Gilbert, Chairman; Herman F. Horlacher.

Finance: George A. Elias, Chairman; James R. Harvey, and Myron Courtney.

Registration: B. Barney Palmer, Chairman; Thomas B. Mullineaux.

Entertainment: Morris L. Hicks, Chairman; Walter D. Taft, Co-Chairman; Frank Sommers, Charles Bowerline, Carl Esche, and J. Salvatorelli.

Inspection Trips: Ralph A. Hoot, Chairman; Max Barofsky, Carmen F. Guarino, Edward D. Bastian, Jacob J. Reich, Roy Hodell, and George Carpenter.

Local Host: Stanley E. Kappe, Chairman; Mrs. Stanley E. Kappe, Mr. and Mrs. John J. Fetch, Mr. and Mrs. Christian T. Beechwood, Mr. and Mrs. John O. Fulmer, Mr. and Mrs. Walter E. Hoover, Jr., Mr. and Mrs. Herman F. Horlacher, Mr. and Mrs. James H. Lynham, Mr. and Mrs. Jerry Magner, Mr. and Mrs. John Yenchko, Robert M. Bolenius, George H. Boone, Donald Jones, George W. Keith, and David A. Evans.

Publicity: Grant A. Howell, Chairman; Joseph McGinty.

Transportation: John T. Cappio, Chairman.

Ladies Entertainment: Mrs. Samuel S. Baxter, Chairman; Mrs. Frank E. Gerlitz, Jr., Mrs. George A. Elias, Mrs. Ralph A. Hoot, Mrs. Samuel I. Zack, Mrs. Romeo A. Falciani, Mrs. Max Barofsky, Mrs. Walter D. Taft, and Mrs. Everett M. Jones.

Reviews and Abstracts*

Radioactivity Levels and Temperature Variations of the Columbia River. By Royal E. Rostenbach. Chem. Eng. Progr. Symposium Series, Nuclear Engineering, *Part V*, **55**, 22 (1959).

Radioactive cooling waters from the Hanford atomic reactors are discharged into the Columbia River. Channeling of the effluents in the river within the Hanford reservation causes the highest concentration of radioisotopes to fluctuate from midstream to the plant shore. Downstream at Richland, Washington, and at McNary Dam the radioactivity is quite uniformly distributed. A substantial reduction in radioactivity takes place as the river flows from the last point of effluent discharge to and through McNary Reservoir. Localized temperature changes due to the effluents are minor in comparison with natural temperature variations of the river and McNary Reservoir.

Author

Tubercle Bacteria Present in Sludge Produced in Mechanical and Biological Sewage Treatment Plants. By G. Müller. *Städtehygiene*, **10**, 5, 96 (May 1959).

Investigations at various sewage treatment works in Germany have indicated that generally tubercle bacteria were present in raw sewage at a rate of about 50 to 100 bacteria per liter. Tubercle bacteria also were found in the sludge produced at sewage treatment works except in sludge thoroughly digested at temperatures of about 85°F. It is concluded that if sewage sludge is to be used for agricultural purposes, sludge treatment in heated digesters or by the application of heat at temperatures of about 140°F may be essential.

W. J. Müller

Research on Aerobic Biological Sewage Treatment at Thermophilic Temperatures. By W. Husmann and F. Malz. *Gas- u. Wasserfach*, **100**, 8, 189 (1959).

Experimental trickling filters with a capacity of seven liters and artificially aerated were operated at 18 and 55°C. The degree of purification obtained at both temperatures did not differ very much but the ammonia content of the effluent from the thermophilic trickling filters was about twice the respective figure of the mesophilic trickling filters. The nitrite and nitrate contents gave the opposite figures. The rate of removal of phenols was found to be equivalent in both types of trickling filters up to a content of 25 mg/l of phenols. At higher concentrations of phenols the mesophilic trickling filter was superior to the thermophilic one.

Experiments with activated sludge treatment on a laboratory scale at temperatures ranging from 20 to 55°C indicated a maximum activity of the sludge at 30°C. Ammonia concentrations were also greater at higher temperatures as was found in the experiments with trickling filters.

W. J. Müller

The Influence of Oxygen Availability on the Degree of Nitrate Reduction by *Pseudomonas Denitrificans*. By V. B. D. Skerman and I. C. MacRae. *Can. Jour. Microbiol.*, **3**, 3, 505 (1957).

Very low oxygen concentration completely inhibited the reduction of nitrate. The amount of nitrate reduced had a linear relationship to the concentration of oxygen in the gas phase. For all concentrations of oxygen in the gas phase at which nitrate reduction occurred the concentration of oxygen in solution remained at zero level. At a concentration of oxygen in the gas phase (10 per cent) which

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Water Pollution Control Federation, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

gave a positive dissolved oxygen level, no nitrate was reduced.

With the low oxygen concentrations in the gas phase which do not give a positive DO level, it is theorized that there exists in solution areas where no oxygen is present and hence a part of the bacterial population is utilizing both molecular and nitrate oxygen, while the rest of the cells are respiring at the expense of molecular oxygen alone even though at some rate lower than maximum. Some organisms attached to the bubble during its transit through the solution may be able to respire at the maximal rate. As the distance of the bacterial cell from the bubble increases, the degree of saturation decreases and the portion of the population respires at a submaximal rate.

H. HEUKELEKIAN

BOOKS, REPORTS, PAMPHLETS

1957 Inventory Municipal and Industrial Waste Facilities. Nine separate volumes, each volume corresponding to the Public Health Service Regions. Public Health Service Publication No. 622. U. S. Department of Health, Education, and Welfare, Public Health Service, Washington, D. C. 1983 pp. total. Price $10.25 (varies from $0.60 to $1.75).

The latest inventory of water pollution facilities throughout the United States.

Potomac River Water Quality Network. Compilation of Data 1950–1957. Interstate Commission on the Potomac River Basin, Washington, D. C. 62 pp.

Writing and Publishing Your Technical Book. F. W. Dodge Corporation, New York. 50 pp. (1959).

How to prepare manuscripts of business, industrial, engineering, and professional books—and how to arrange for their publication.

A Preliminary Investigation of Nutrients in Western Lake Superior 1958-1959. By HUGH D. PUTNAM, THEODORE A. OLSON, HERBERT M. BOSCH, AND THERON O. ODLANG. School of Public Health, University of Minnesota, Minneapolis, Minn. (June 1959).

The third in a series of limnological studies of Lake Superior.

Compendium of Water Pollution Laws. PREPARED BY CARL E. GEUTHER. Water Pollution Abatement Manual W-5, Manufacturing Chemists Association, Inc., Washington, D. C. Price $5.00 (1959).

Fifty-three chapters covering the laws of the 50 states, federal laws, and those of the District of Columbia and Puerto Rico pertaining to water pollution. Each chapter describes the organization of a water pollution control agency, describes the water pollution abatement policy, gives a resumé of the law, and briefly outlines the rules and regulations in force.

The Municipal Year Book 1959. EDITED BY ORIN F. NOLTING, DAVID S. ARNOLD, AND JOHN J. HUNNEWELL. The International City Managers' Association, Chicago. 606 pp. Price $10.00 (1959).

A comprehensive view of urban government in the United States, containing 22 major tables, with detailed information about organization, personnel, finances, and activities of cities. Highlights of this edition include special sections on urban renewal and economic classification of cities. New material is presented on special assessments in 876 cities over 10,000 population: improvements financed by special assessment, methods of financing, allocation of costs to property owners, city participation in financing, and latest issue of special assessment bonds. New information is given on special censuses for cities over 5,000 population, annexation, and other metropolitan area developments, zoning requirements for residential lots, and fire and police data on education and training requirements.

Progress in Nuclear Energy. Series III. Process Chemistry. Vol. 2, 1st edition. EDITED BY F. R. BRUCE, J. M. FLETCHER, AND H. H. HYMAN. Pergamon Press, New York, London, Paris, Los Angeles. 579 pp. Price $17.50 (March 1959).

A collection of papers dealing with many aspects of nuclear chemistry. Papers on waste processing are: "The Fixation of Highly Active Wastes in Solid Form," By C. B. AMPHLETT; "Processing and Disposal of Low-Level Wastes," By D. C. SAMMON; "Waste Processing: Windscale Philosophy and Arrangements," By K. SADDINGTON; "Ultimate Disposal of Radioactive Wastes," By W. A. RODGER AND P. FINEMAN.

Summary Preliminary Report on Ground-Water Resources of the Chicago Region, Illinois. By Max Suter, Robert E. Bergstrom, H. F. Smith, Grover H. Emrich, W. C. Walton, and T. E. Larson. Cooperative Ground-Water Report 1-S, State Water Survey and State Geological Survey. State of Illinois, Department of Registration and Education, Springfield, Illinois. 18 pp. (1959).

Investigation of Current Measurement in Estuarine and Coastal Waters. By J. W. Johnson and R. L. Wiegel for the State Water Pollution Control Board, Sacramento, Calif. Publication No. 19. 233 pp. Price $1.75 (1959).

A report made as part of a contract to investigate the existing and potential systems for measuring currents in both coastal and estuarine waters, as such currents relate to the movement, transport, and dispersion of discharged wastewater. Characteristics of both currents and measuring devices are reported on in detail. Main topics covered are: general character of ocean currents, determination of coastal and estuarine currents, rotating element current meters, drift type current measuring systems and position surveying, miscellaneous types of current meters, and data recording and analysis. Procedures are summarized and equipment suggestions are made.

Water for Your Ever-Expanding Needs. Delaware River Basin Research, Inc., Philadelphia, Pa. 20 pp. (1959).

Odor Measurement and Control. The Franklin Institute Laboratories for Research and Development, Philadelphia, Pa. 82 pp. Price $3.00 (1959).

Proceedings of the Third Annual Symposium on Problems in Air Pollution held at the Franklin Institute on October 21, 1958.

Streams of Progress. Alabama Water Improvement Commission, Montgomery, Ala. (1959).

A public relations brochure.

Proceedings, 7th Annual Pennsylvania Clean Streams Conference. Pennsylvania State Chamber of Commerce, Harrisburg, Pa. 35 pp. Price $1.00 (1959).

The full proceedings of the meeting held at Reading, April 24, 1959.

Algae in Water Supplies. By C. Mervin Palmer. U. S. Department of Health, Education, and Welfare, Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Public Health Service Publication No. 657. 88 pp. Price $1.00 (1959).

An illustrated manual on the identification, significance, and control of algae in water supplies. Includes 6 color plates of algae species.

Sample Type VI Water-Surfactant. By Robert C. Kroner, Raymond J. Lishka, and Harold L. Faig. Analytical Reference Service, Training Program, Robert A. Taft Sanitary Engineering Center, U. S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio.

Final report on Analytical Reference Service, sample type VI (water, surfactant).

Oceanographic Survey of the Continental Shelf Area of Southern California. Publication No. 20, State Water Pollution Control Board, Sacramento, Calif. 560 pp. Price $4.00 (1959).

The results of a study by the Allan Hancock Foundation of the University of Southern California at Los Angeles on marine sewage disposal. The report includes the topics of marine climate, sediments, physical and chemical characteristics of the water, benthic marine flora, benthic biology, and microbiology.

1958 Proceedings of the Oklahoma Water, Sewage and Industrial Wastes Association. Part 1. Industrial Wastes Conference. Part 2. Water and Sewage Short Course. Edited by Quintin B. Graves. Oklahoma State University, Stillwater, Okla. 124 pp. (1959).

Scientific Papers from Institute of Chemical Technology, Prague, 1957, Faculty of Technology of Fuel and Water. Laboratory of Hydrobiology, Department of Water Technology, Praha, Czechoslovakia. 345 pp. (1957).

Scientific Papers from Institute of Chemical Technology, Prague, 1958, Faculty of Technology of Fuel and Water. Laboratory of Hydrobiology, Department of Water Technology, Praha, Czechoslovakia. 436 pp. (1958).

Eighteenmile Creek Drainage Basin and Other Tributaries entering Lake Ontario Between Niagara River and Eighteen Mile Creek. Lake Ontario Drainage Basin Survey Series Report No. 3, New York State Department of Health, Water Pollution Control Board, Albany, N. Y. 71 pp. (1959).

Community Facilities, A List of Selected References. National Housing Center Library, Bibliography Series No. 4, National Association of Home Builders, Washington, D. C. 170 pp. (Aug. 1959).

A reference list intended to provide assistance to planners, government officials, educators, engineers, builders, and others concerned with orderly community growth.

Proceedings Conference on Man Versus Environment. Edited by Harry A. Faber, Assisted by Marie H. Peak. U. S. Department of Health, Education, and Welfare, National Institutes of Health and Public Health Service, Washington, D. C. 143 pp. (1959).

A compilation of the papers given at the Man Versus Environment Conference in Washington May 5-6, 1958.

Scientific Papers from Institute of Chemical Technology, Prague, 1958, Faculty of Technology of Fuel and Water 2, Part 2. Laboratory of Hydrobiology, Department of Water Technology, Praha, Czechoslovakia. 575 pp. (1958).

Manual of Instruction for Water Treatment Plant Operators. By Bureau of Environmental Sanitation and Office of Professional Training. New York State Department of Health, Albany, N. Y. Distributed outside New York State by Health Education Service, P. O. Box 7283, Albany 1, N. Y. 168 pp. Price, $1.00 (1959).

A water treatment plant operator's manual written for the Grade II Water Plant Operator's course. Emphasis is placed on fundamental principles of water supply.

Ohio River Valley Water Sanitation Commission—1959, Eleventh Annual Summary. Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio. 8 pp. (1959).

Illustrated annual report to the Governors of the eight States.

Papers Presented at Sixth Ontario Industrial Waste Conference. The Water and Pollution Advisory Committee of the Ontario Resources Commission, Toronto, Ontario. 306 pp. (1960).

The proceedings of the 1959 Ontario Industrial Waste Conference. Also contains an index to the first six proceedings.

Report on Research Carried Out by the Public Health Engineering Section in the Year Ended 30 June 1959. University of Durham, King's College, Department of Civil Engineering, Newcastle Upon Tyne, England, Bull. No. 18. 28 pp. (1960).

A report of several research projects carried on with wastewater problems in Great Britain.

List of Technical Studies by the Federal Housing Administration, in Cooperation with: Technical Studies Advisory Committee and Building Research Advisory Board of the National Academy of Sciences—National Research Council. Federal Housing Administration, Washington, D. C., FHA No. 470. 37 pp.

A list with brief descriptions of studies under contract, under consideration, and potential studies. Includes several of interest to the wastewater field.

Hydrology. 2nd Edition. By C. O. Wisler and E. F. Brater. John Wiley & Sons, Inc., New York. 408 pp. Price, $9.25 (1959).

This revision of the earlier reference book adds a method for the determination of the magnitude of floods that may be expected to occur with specified rare frequencies on any given stream. New coverage includes hydrology of semi-arid basins, and the effect of snow on the hydrology of an area. Other problems discussed include determination of spillway and bridge discharge capacities, methods of flood reduction, water conservation practices, evaluation of potential water power on a river, and evaluation of amount of water available for water supply or waste disposal on a river.

Proceedings—8th Annual Pennsylvania Clean Streams Conference. Pennsylvania State Chamber of Commerce, Harrisburg, Pa. 36 pp. Price, $1.00.

JOURNAL PUBLICATION PROCEDURES

The Journal of the Water Pollution Control Federation depends heavily on the program of its Member Association meetings as a source of technical material.

To assist the Journal maintain a high degree of uniformity and quality of editorial material, certain rules have been established governing publication procedures.

These rules, as prepared by the Federation's Publications Committee and approved by the Board of Control in October 1941, are reproduced herewith:

1. All papers presented before the meetings of the Federation or before any of its Member Associations become the property of the Federation, and publication of these in any but the Federation publications can be made only with specific permission from the Publications Committee.

2. Papers shall be submitted to the Editor of the Journal of the Water Pollution Control Federation in proper form, for publication in that JOURNAL. One copy of the paper, complete with diagrams, charts, sketches, and bibliography, shall be submitted.

3. The Editor of the Journal of the Water Pollution Control Federation shall judge the suitability of any paper for publication. In case any paper is rejected, the Editor shall notify the author within thirty days of the reasons for rejection. Should any disagreement between the Editor and author arise regarding publication, the matter shall be referred to the Publications Committee for adjudication and its decision shall be final.

4. The Editor of the JOURNAL shall make any editorial changes in format or content which he may consider necessary and these shall be referred to the author in galley proof. Objections to editorial changes shall be referred by the author within seven days to the Editor and the Publications Committee and the decision of the Publications Committee shall be final.

5. The date of publication of any paper shall be left to the discretion of the Editor of the JOURNAL. Any questions regarding date of publication shall be referred to the Publications Committee and its decision shall be final.

6. Papers for publication in the Journal of the Water Pollution Control Federation which have not been presented at a meeting of the Federation or of any Member Association shall be referred to the Editor for decision as to their suitability for publication. Any disagreement between the author and the Editor relative to the publication of such papers shall be referred to the Publications Committee and its decision shall be final.

7. Special publications issued in the name of the Water Pollution Control Federation shall be referred to the Editor and Publications Committee for review prior to publication.

In interpreting the above rules, there is no intent to interfere with the production of proceedings, bulletins, or reports wherein the Member Association distributes the papers presented at its meetings to its own membership. Where any doubt arises in regard to the interpretation of these rules it is suggested that the matter be taken up with the Executive Secretary-Editor of the Federation.

AWARDS

Arthur Sidney Bedell Award

Member Associations are privileged to nominate a recipient for the Federation's Arthur Sidney Bedell Award, which is given "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Member Associations."

By action of the Board of Control on October 14, 1951, nominations by the Member Associations of recipients of the Arthur Sidney Bedell Award shall be made in accordance with the following rules:

1. The number and frequency of awards per Member Association shall be as follows:

0 to 34 members...by petition only
35 to 249 members...1 per three years
250 to 499 members...2 per three years
500 to 749 members...3 per three years

but that if any Member Association in the 0- to 34-class increases its membership by 50 per cent and is still under 35 members, it shall by petition be favorably considered for an award before reaching the 35-member status to allow eligibility for one nomination in a 3-year period.

2. No Member Association shall nominate more than one recipient per year.

3. The Awards for the succeeding year shall be made in accordance with the schedule and reviewed as to eligibility as of the preceding September 30.

Each December issue of the Journal of the Water Pollution Control Federation carries the current Awards schedule. The rotation and frequency of this award is the same as the Hatfield Award.

The Member Association is allowed full freedom to establish its own criteria for the selection of the winner of this award. Leadership in the organization or administration of the Member Association, membership activity, technical contributions bringing prestige to the Member Association, etc., are criteria that might be applicable. Each nominee must be an Active Member of the Member Association.

The presentation of the Federation award is most appropriately arranged as a part of the meeting of the Member Association following approval by the Board of Control.

William D. Hatfield Award

By action of the Federation Board of Control, on October 9, 1955, and subsequent action by the Federation Executive Committee, a revised procedure for selecting nominated recipients of this award was adopted.

The purpose of the William D. Hatfield Award is to recognize operators of sewage and waste treatment plants who are doing an outstanding job in performance of their duties as well as to operators demonstrating distinguished professionalism. The aspects of plant operation on which the award is based serve these purposes:

1. Encourage better public relations between the plant operator and the public.

2. Recognize businesslike accounting of expenditure of funds and care of the treatment plant and accessories entrusted to the operator.

3. Recognize the outstanding reports

which serve the requirements of the operator's superior officials and provide a basis for recommendations by the operator for improvements to his plant for better efficiency of treatment and economy of operation.

4. Advancement of the art and knowledge of sewage and waste treatment by dissemination to other engineers and operators the basic information and data concerning a particular plant and process through papers, articles, meetings, and reports.

The schedule entitles each Member Association to name one of its operator members to receive the Federation's Hatfield Award, provided the operator has not previously been the recipient of such an award. Operators of industrial wastes treatment plants as well as operators of municipal and privately-owned sewage treatment plants are eligible. Each nominee must be an Active Member of the Member Association.

The rotation and frequency of the award is the same as the Bedell Award, with the schedule published in each December issue of the Journal of the Water Pollution Control Federation.

The presentation of this award will take place at the same Member Association meeting during which a Bedell presentation will be made and would ordinarily be the meeting following approval by the Federation Board of Control.

Basis of Nomination

The Member Association is allowed freedom in establishing its procedure and criteria for selection of its winner of this award. It is suggested that recommendations as to outstanding operators be solicited from the various state health departments and that the Member Association appoint a "Plant Operation and Operator Awards Committee" to make the selections.

As a guide in determining the recipients, the following basis of selection is recommended:

Item	Maximum Percentage Points
Efficiency of treatment, considering available facilities, and effects of plant effluents on receiving waters	25
Good housekeeping	10
Public relations	10
In-service training and certification of subordinate operators	5
Emergency operation	5
Compilation of and dissemination of routine operation data to regulatory agencies and to the profession	15
Preparation and dissemination of annual report	15
Preventive maintenance and safety	10
General administration	5
Total	100

Notification Regarding Selection

The nominees for the Arthur Sidney Bedell and W. D. Hatfield Awards must be determined by the Member Association and the Secretary of the Association must notify the Executive Secretary of the Federation of the name of the individuals being nominated for these awards on or before September 1 of the year in which the nominations are recommended to the Federation Board of Control. The Member Association Secretary shall give the individuals' names as they are to appear on the certificate at the time their nominations are transmitted.

WPCF PUBLICATIONS

JOURNAL of the WATER POLLUTION CONTROL FEDERATION (SEWAGE AND INDUSTRIAL WASTES until January 1960)

Official monthly publication of the Water Pollution Control Federation. An average of over 1,100 text pages annually affords coverage of all phases of research, design, construction, operation and management of works for the collection and treatment of sewage and industrial wastes as well as research and administration in stream pollution control and abatement. Major part of published material comes from technical programs presented at meetings of the Federation and its Member Associations. Edited by Ralph E. Fuhrman, Executive Secretary of the Federation. Single copies: U.S.A. and Canada, $1.25 each. Foreign, $1.50 each. Subscriptions: U.S.A. and Canada, $10.00 for one year. Foreign, $11.50 for one year.

TWENTY-YEAR INDEX TO SEWAGE WORKS JOURNAL

The first twenty volumes (115 numbers) of SEWAGE WORKS JOURNAL, covering the period 1928 through 1948, encompass an era of great progress in sewage and industrial wastes disposal. This index comprises three main sections, with listing by author, subject, and geographical location. Entries include the entire content of the JOURNAL—papers, editorials, committee reports, abstracts, Federation affairs, and fillers. Special attention has been given to the emphasis of key words and to cross-indexing. It is designed to lead the searcher to the reference quickly. 144 pages, bound in buckram. Price $3.00.

TEN-YEAR INDEX TO SEWAGE AND INDUSTRIAL WASTES

Volumes 21 through 30 of SEWAGE AND INDUSTRIAL WASTES (volume 21 was SEWAGE WORKS JOURNAL) covering the period 1949 through 1958. This index continues the pattern set by the earlier Twenty-Year Index in its three main sections of author, subject, and geographical listings. The Index reflects special care in providing entries which are easy to locate and identify. Liberal use of multiple listings are included to facilitate ease and effectiveness to the user. 168 pages, in buckram, $4.00; and in heavy paper, $3.00.

GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING

Prepared by a joint committee representing FSIWA, ASCE, AWWA, and APHA. Contains 2,600 terms pertaining to nomenclature of hydrologic, hydraulic and sewage works engineering fields. Paper cover edition $1.00.

Manual of Practice No. 1—SAFETY IN WASTEWATER WORKS

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Manual of Practice No. 2—UTILIZATION OF SEWAGE SLUDGE AS FERTILIZER

Prepared by FSIWA Sewage Works Practice Subcommittee on Sludge Utilization for Fertilizer. An authorita-

tive evaluation of the advantages and limitations of sewage sludge as a soil conditioner. Contains 45 tables, 251 references. 120 pages. Single copies $1.25 each.

Manual of Practice No. 4—CHLORINATION OF SEWAGE AND INDUSTRIAL WASTES

A 90-page bulletin prepared by FSIWA Committee on Chlorination of Sewage. Reviews the history, development, and up-to-date technique of chlorine application in all aspects of the treatment and disposal of waterborne wastes. Includes a selected classified bibliography of more than 350 references. Single copies $1.25 each.

Manual of Practice No. 5—AIR DIFFUSION IN SEWAGE WORKS

Prepared by the FSIWA Committee on Air Diffusion, this Manual is a practical and useful guide to designers and operators of sewage works and industrial wastes treatment plants. The Manual traces the history of air diffusion as applied in sewage treatment, and outlines modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. Bibliography of 61 references. 75 pages. Single copies $1.25 each.

Manual of Practice No. 6—UNITS OF EXPRESSION FOR WASTES AND WASTE TREATMENT

Prepared by the FSIWA Subcommittee on Units of Expression, this Manual lists recommended units for quantities ordinarily encountered in wastes and waste treatment. It attempts to eliminate the heterogeneous units which have grown into sewage and industrial wastes practices. 8 pages. Single copies 50¢ each.

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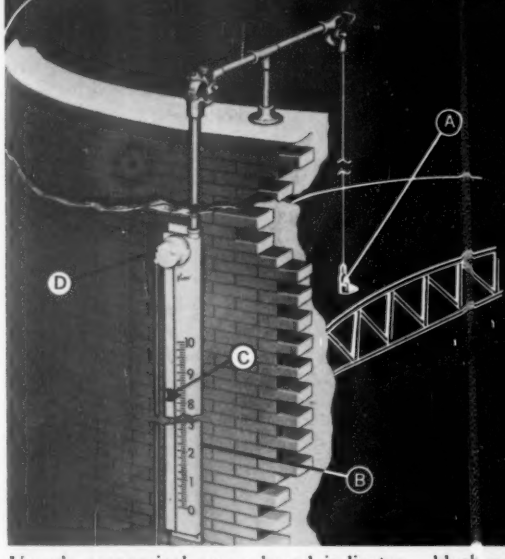

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DO Recorder—An automatic dissolved oxygen recorder based on titrimetric principles is manufactured by Baird and Tatlock, Ltd., London, England, and is distributed in the United States by the Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago 22, Ill. It is expected to cost between $5,000 and $7,000. Complete literature is available from the distributor.

DO recorder

Flow Tube—The Burgess-Manning Company, Penn Instruments Division, 4110 Haverford Ave., Philadelphia 4, Pa., has a new design for a short flow tube. "Lo-Loss" tubes come in cast iron, bronze, stainless steel, or plastic.

Screens—Applications and specifications for Conidure pierced metal and Rima slit screens are described in Bulletin C101 of Cross Perforated Metals, National-Standard Co., Niles, Mich.

Grease Cleaner—What is said to be a safe, inexpensive chemical cleaner is being marketed to remove grease from sludge lines. Supplied as a liquid concentrate, F.O. 287 is a viscous, water-soluble mixture of surface active agents, a heavy-duty detergent, and a corrosion inhibitor.—Fine Organics, Inc., 205 Main St., Lodi, N. J.

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Recording pH Meter—A combined pH meter and strip-chart recorder is designed to sell for $195 f.o.b. Chatham, N. J. A switch on the front panel permits disconnection of the chart drive so that the instrument becomes an indicating pH meter. Chart speeds are available ranging from one to sixteen inches per hour.—Brochure No. 3-R, Analytical Measurements, Inc., 585 Main St., Chatham, N. J.

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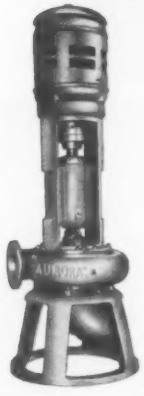

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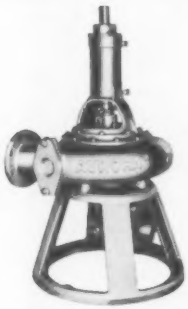

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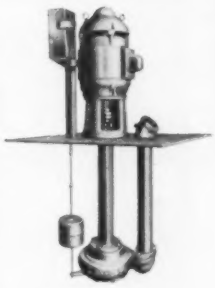

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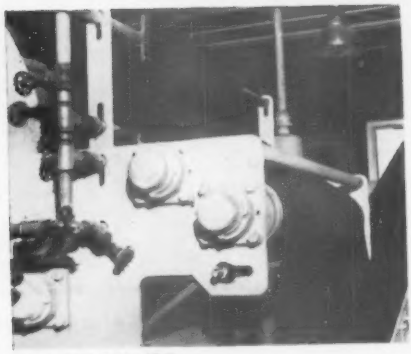
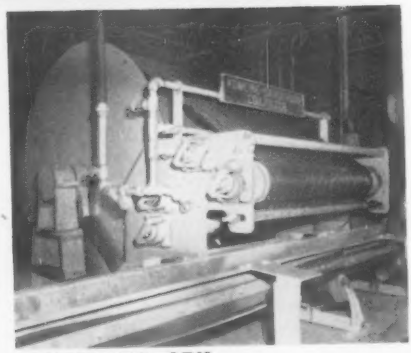


SULLIVAN, ILL.
ENGINEERS: GEORGE L. SODEMANN & ASSOC.



JONESBORO, ARK.
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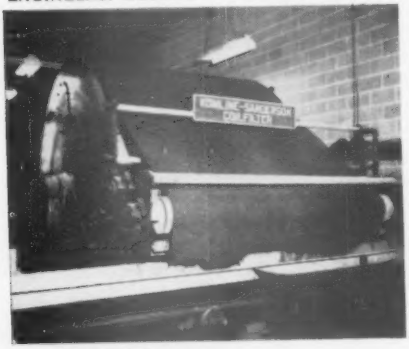

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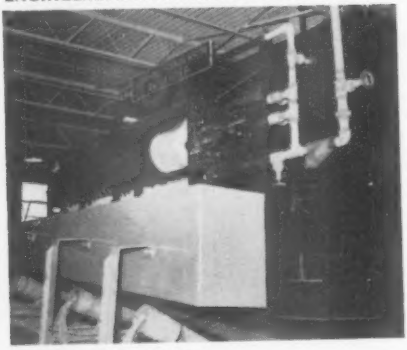

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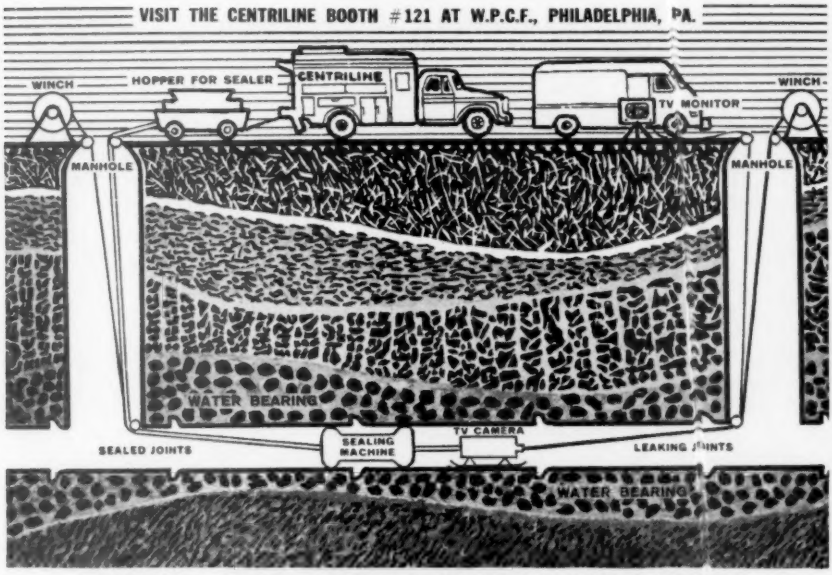

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Proceedings of Member Associations

WEST VIRGINIA WATER POLLUTION CONTROL ASSOCIATION

The 14th Annual Meeting of the West Virginia Water Pollution Control Association was held in conjunction with the annual meeting of the West Virginia Section of the American Water Works Association. The joint meeting was held at the Pritchard Hotel, Huntington, W. Va., Mar. 23–24, 1960.

These papers of interest to sewage and industrial wastes personnel were presented:

"Current Observations on Aerobic Digestion Plants in Ohio," by Homer Knox, Sanitary Engineer, Ohio Department of Health, Columbus, Ohio.

"Flexible Joints for Sewer Pipe," by William D. Kelley, Kelley, Gidley & Staub, Inc., Charleston, W. Va.

"Biological Oxidation of Organic Chemical Wastes in Stabilization Ponds," by William M. Steinfeldt, Eastman Kodak Co., Rochester, N. Y., and Jack T. Garrett, Monsanto Chemical Co., St. Louis, Mo.

"ORSANCO and Ohio River Water Quality," by F. W. Montanari, Sanitary Engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

"Why Paints Fail," by E. J. Sirmay, Vice-President, Tropical Paint Co., Cleveland, Ohio.

"Factors in Acceptance of a Metal Plating Waste by a Municipal Sewage Treatment Plant," by Carl L. West, Bacteriologist, Marietta, Ohio.

(*Continued on page 492a*)

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"Federation Activities," by W. D. Hatfield, Past-President of the Federation.

"Cyanide and Chrome In-plant Pollution Abatement," by Leo Carrol, Senior Systems Engineer, Fischer and Porter Co., Warminster, Pa.

"Certification of Sewage Treatment Plant Operators," by G. O. Fortney, Chief, Engineering Section, Division of Sanitary Engineering, Department of Health, Charleston, W. Va.

At the business meeting, final action was taken to change the Association's name to the West Virginia Water Pollution Control Association.

The following officers were elected to serve during the year 1960–61:

President: Rex C. Pierson, Charleston.
Vice-President: Richard L. Williams, South Charleston.
2nd Vice-President: Bern Wright, Charleston.
Secretary-Treasurer: Glen O. Fortney, Charleston.

GLEN O. FORTNEY
Secretary-Treasurer

TEXAS WATER AND SEWAGE WORKS ASSOCIATION

The Texas Water and Sewage Works Association held its Annual Meeting at the Memorial Student Center, Texas A. & M. College, College Station, Tex., Feb. 28–Mar. 1, 1960. The meeting was held in conjunction with the 42nd Texas Water and Sewage Works Association's Short School. Registration totaled 751.

At technical sessions no phase of wastewater handling was neglected. Among the subjects discussed were: bio-oxidation of industrial wastes, job classifications and salary scales, safety, plant beautification, maintenance, water conservation, operational features of new plants, industrial waste ordinances, sewer relocation, current research, injection wells, effluent reuse, and neutralization.

(*Continued on page 494a*)

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At the business luncheon of the Sewage and Industrial Wastes Section, W. D. Hatfield, Federation Past-President, reported on Federation activities and presented the Bedell Award for distinguished personal service to the Section to C. H. Connell, Professor of Preventive Medicine and Public Health, University of Texas, Medical Branch, Galveston, Tex. The Hatfield Award for outstanding treatment plant operation went to W. N. Wells, Superintendent of Sewage Treatment, San Antonio, Tex.

Officers elected for the year 1960–61 are:

Chairman: Cecil H. Williams, Dallas.
1st Vice-President: John P. Wold, Pasadena.
2nd Vice-President: William N. Wells, San Antonio.
Secretary: G. R. Herzik, Jr., Austin.
Asst. Secretary-Treasurer: Mrs. Earl H. Goodwin, Austin.
Director: J. L. Robinson, Fort Worth.

Mrs. Earl H. Goodwin
Asst. Secretary-Treasurer

UTAH SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Utah Sewage and Industrial Wastes Association held its 3rd Annual Meeting at the University of Utah Union, Salt Lake City, Utah, on Feb. 1 and 2, 1960. The meeting was held in conjunction with the 11th Municipal Water and Sewage Works School. Total registration exceeded 180.

The technical program covered three half-day sessions, and a field trip occupied the fourth half-day to round out the two-day program. Presentations devoted to wastewater handling included:

(*Continued on page 497a*)

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Reviews history, development, and up-to-date technique of chlorine application. *90 pages. $1.00 to members; $1.25 to others. Order as MOP-4.**

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History and modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. *75 pages. $1.00 to members; $1.25 to others. Order as Item MOP-5.**

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WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL.

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Bins, Storage (*see* Tanks)

Biologists (*see* Directory of Engineers)

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"Management of a Sanitary District," by W. T. South, Manager, Salt Lake Suburban Sanitary District.

"ABC's of Sewage Treatment," by J. D. Walker, President, Walker Process Equipment, Inc., Aurora, Ill.

"Standards for Grease Traps," by M. C. Hope, Chief, General Engineering Branch, U. S. Public Health Service, Washington, D. C.

"Pump Maintenance," by R. H. Nickerson, Nickerson Pump and Machinery Co., Salt Lake City, Utah.

"Chlorinator Operation," by H. M. Hurst, Sanitary Engineer, Utah Department of Health, Salt Lake City, Utah.

The luncheon speaker was Dr. W. J. Cope of Space Technology Laboratories Inc., Los Angeles, Calif., who spoke on the intriguing subject—space sanitation.

At the business session, the name of the Utah association was changed to the Utah Water Pollution Control Association.

The following officers were elected to serve for the year 1960–61:

President: Emil Meyer, Salt Lake City.
Vice-President: Harold A. Linke, Jr., Salt Lake City.
Director: Wm. W. Anderton, Salt Lake City.
Secretary-Treasurer: Howard M. Hurst, Salt Lake City.

HOWARD M. HURST
Secretary-Treasurer

KANSAS SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 14th Annual Joint Meeting of the Kansas Sewage and Industrial Wastes Association and the Kansas Section of the American Water Works Association was held at the Besse Hotel, Pittsburg, Kans., on Apr. 22–24, 1959. Registration totaled 223 which included 25 ladies.

Portions of the technical sessions of interest to individuals in the wastes treatment field included:

A discussion of "Maintenance and Operation of Clarifiers and Settling Equipment" by E. C. Cardwell, Dorr-Oliver Inc., Chicago, Ill.

A discussion of the "Effect of Industrial Wastes on Design and Operation of Sewage Treatment Plants" by Robert E. Crawford, Wilson and Company, Salina, Kans.

A discussion of "Digester Operation with Gas Recirculation" by Roger Lee, superintendent of sewage treatment, Wichita, Kans.

The following new officers were elected for 1959:

Chairman: Wilbur Moffatt, Chanute.
1st Vice-Chairman: Chester Goble, Hutchinson.
Director: Roger D. Lee, Wichita.
Secretary-Treasurer: Howard F. Saiger, Wichita.

HOWARD F. SAIGER
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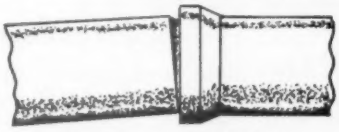
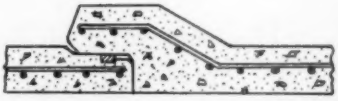


PIPE SIZE	DEFLECTION
12"	2° 00'
15"	1° 48'
18"	1° 36'
21"	1° 22'
24"	1° 12'
27"	1° 04'
30"	0° 58'
33"	0° 52'
36"	0° 48'
42"	0° 41'
48"	0° 36'
54"	0° 32'



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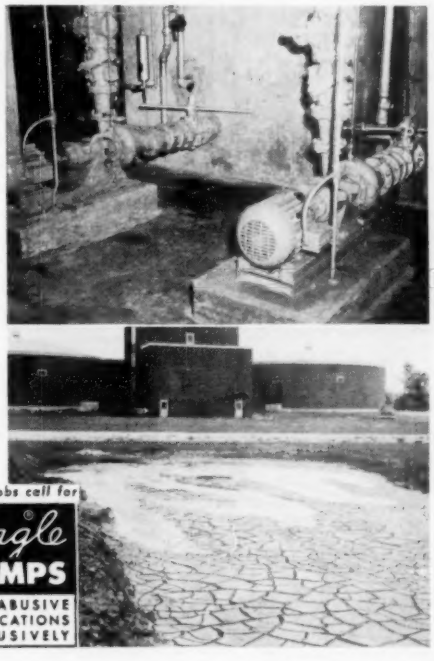

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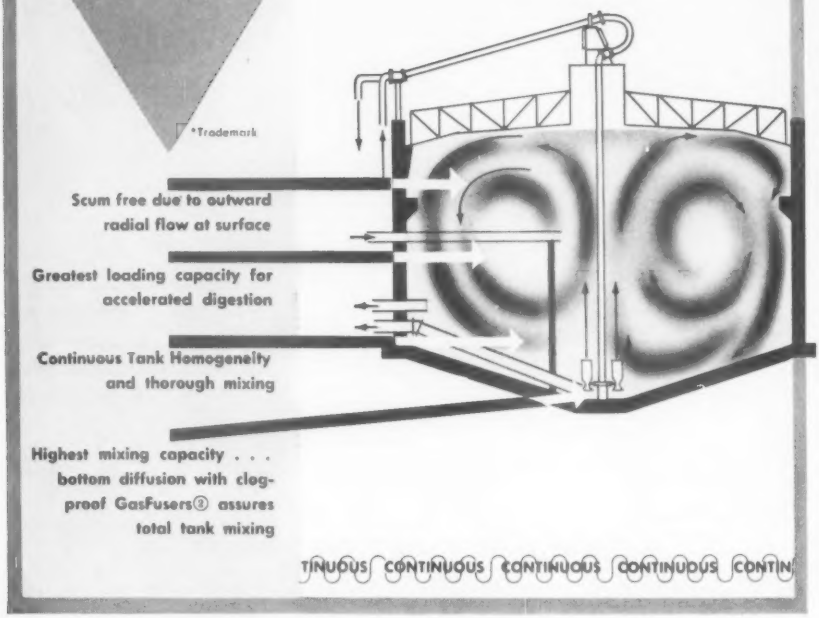
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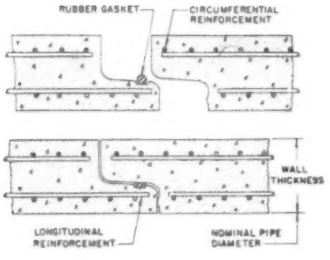

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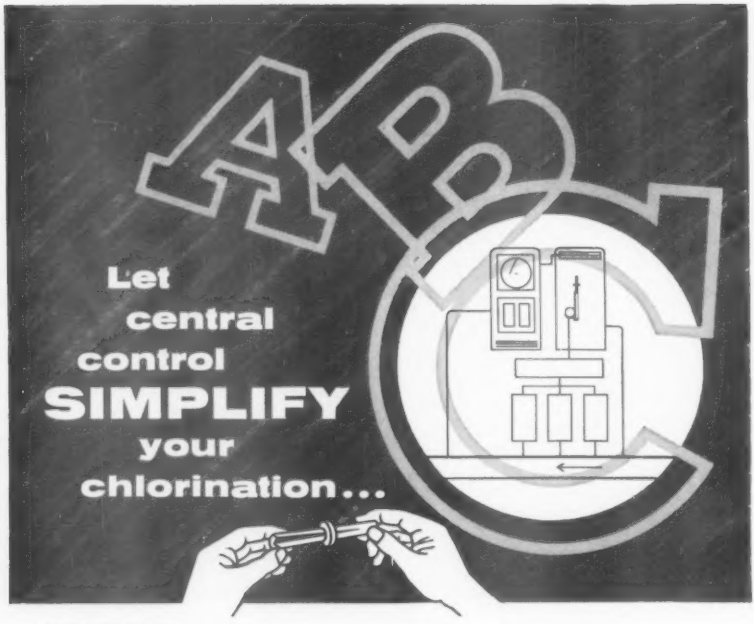
Lock Joint's Rubber and Concrete Joint, available in this type of pipe and in some designs of conventionally cast pipe, gives maximum protection against infiltration while affording ample flexibility to accommodate deflections due to ground settlement and expansion of contraction due to temperature changes.

For economy in jointing, Roller Suspension Pipe is produced in standard 8′ lengths and is available in diameters from 12″ to 72″. Lock Joint Pipe Company also produces machine made and cast pipe ranging in diameter from 6″ to 120″ or even larger if required. All Lock Joint sewer and culvert pipe may be designed to comply with A.S.T.M., State Highway or individual specifications.

LOCK JOINT PIPE CO.

East Orange, New Jersey

Pressure • Water • Sewer • **REINFORCED CONCRETE PIPE** • Culvert • Subaqueous



W&T **COMPOUND-LOOP CONTROL**

By residual analysis and information feedback, Wallace & Tiernan Compound-loop Control adjusts chlorinator feed rates to changing water flows and chlorine demands. You can add W&T Remote Residual Recording and Controlling Components throughout your water system and centralize control at any desired location. You select the desired residual on a central panel and the Compound-loop System maintains that residual faithfully.

Remote recording by W&T gives you duplicate residual records and minute-to-minute information where it helps guide operation. Remote controlling by W&T lets you adjust a chlorinator miles away. And W&T Remote Components adapt to almost any system, any type of control.

With remote residual recording and controlling by Wallace & Tiernan you centralize control... save time and operating expense... extend the advantages of the Compound-loop method.

For more information, write Dept. S-142.84

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